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EVALUATION AND DISPOSAL OF WASTE MATERIALS WITHIN 19 TEST LYSIMETERS AT CENTER HILL

by

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EPA Contract No. 68-03-3210-04

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This report describes the termination of a ten-year experimental landfill co-disposal project. Nineteen simulated landfills were constructed in 1974 and 1975 and operated until September 1983. Data collected during this termination study included observations of overall test cell conditions; chemical analysis of final leachate, refuse and bottom gravel; physical analysis of refuse, gravel, and clay conditions; microbiological analysis of the refuse; and in-place permeability and specific yield of the refuse. Comparisons between municipal refuse-only cells and municipal refuse/industrial sludge co-disposal cells were made in order to evaluate the effect the industrial sludges had on the decomposition process.

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications.

The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs, and regulations of the Environmental Protection Agency, the permitting and other responsibilities of state and local governments, and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report describes the condition of various municipal and industrial wastes after disposal for ten years in experimental landfills and will be useful to designers, engineers, planners, municipal, state and federal officials.

For further information, please contact the Land Pollution Control Division of the Hazardous Waste Engineering Research Laboratory.

William A. Cauley,
Acting Director
Hazardous Waste Engineering
Research Laboratory

ABSTRACT

This report describes the termination of a ten-year experimental landfill codisposal project. Nineteen simulated landfills were constructed in 1974 and 1975 and operated until September 1983. Data collected during this termination study included observations of overall test cell conditions; chemical analysis of final leachate, refuse and bottom gravel; physical analysis of refuse, gravel, and clay conditions; microbiological analysis of the refuse; and in-place permeability and specific yield of the refuse. Comparisons between municipal refuse only cells and municipal refuse/industrial sludge codisposal cells were made in order to evaluate the effect the industrial sludges had on the decomposition process.

The codisposal cells did not appear to be different from the municipal refuse only cells in terms of any of the parameters analyzed. Large numbers of aerobic, anaerobic and facultative microorganisms, many of which were pathogens, were found in both types of cells. It appeared that the decomposition process was more inhibited by the presence of intact plastic or paper bags and other protective wrappings than by the presence of sludges from battery production, plating operations, chlorine production, water softening, paint pigments, solvent-based paints, petroleum processing or municipal wastewater treatment. Identifiable food wastes and other readily biodegradable materials, including fecal matter in disposable diapers, were found protected from decomposition by such wrappings.

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SECTION 1

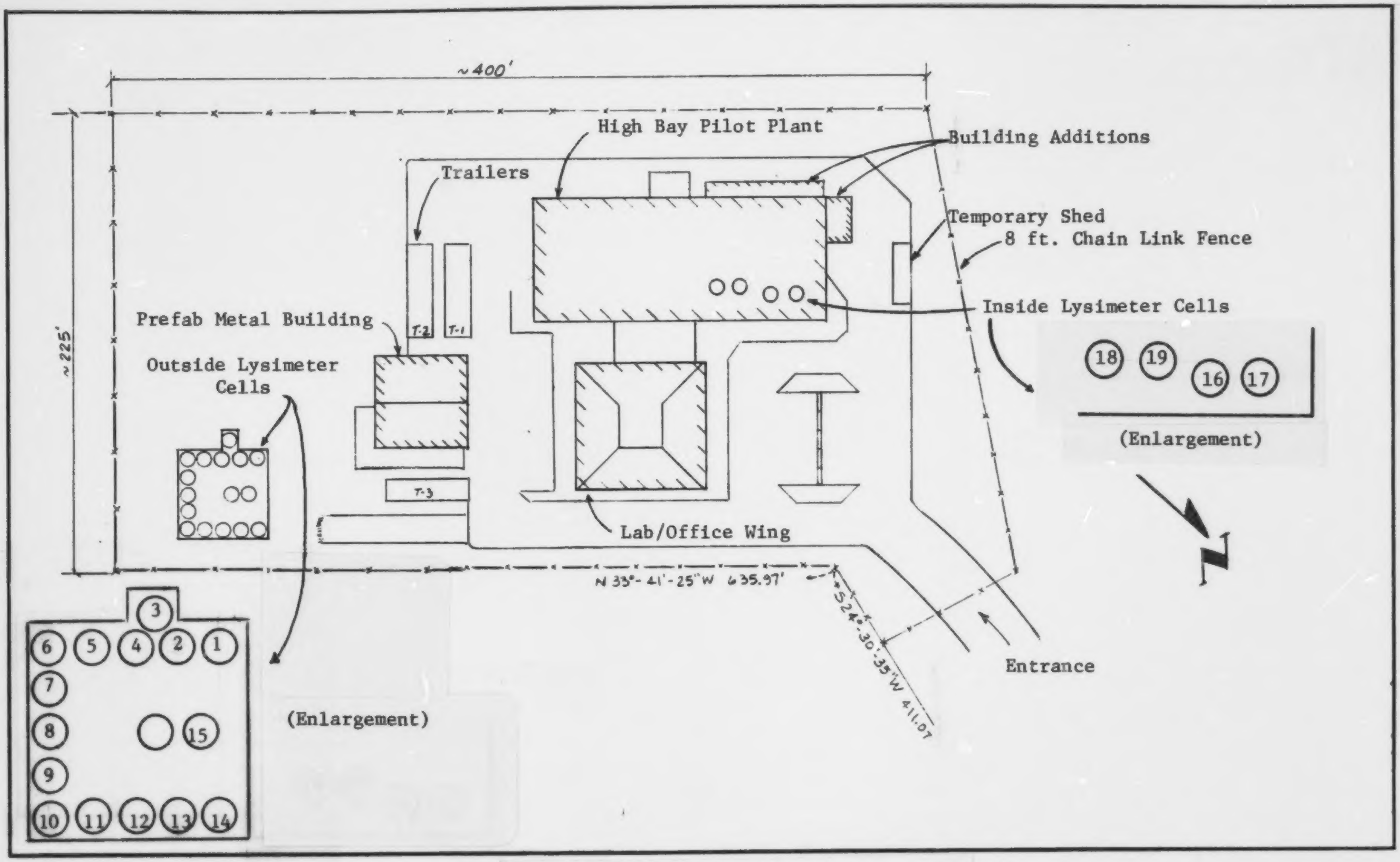
INTRODUCTION

BACKGROUND

This report covers the termination of a 10-year pilot scale sanitary landfill co-disposal project at the US EPA Center Hill Solid and Hazardous Waste Research Facility in Cincinnati, Ohio. The project consisted of 19 simulated sanitary landfills, each loaded with varying municipal refuse/ industrial refuse combinations. Four of the lysimeters were located inside the high bay of the facility and fifteen lysimeters were located outside in the ambient environment (Figure 1). The outside cells were buried in the ground to within six inches of their tops.

All lysimeters were constructed of steel tubes six feet (1.8 m) in diameter and twelve feet (3.7 m) high. The steel sidewalls were coated inside with coal tar epoxy as a moisture seal. Several layers of fiberglass-coated cloth were placed inside at the base of the cells and extended one foot (0.3 m) up the sidewall to provide a watertight and gastight seal. Each cell had provisions for leachate drainage, water input, a gas probe connector and temperature probe connectors. Each connection was caulked to maintain a watertight and gastight cell.

Although the cells varied in their actual waste components, all cells were loaded in a similar manner. First, a six-inch (15.2 cm) layer of silica gravel was placed in each cell. This was intended to act as a reservoir for leachate and prevent refuse from clogging the leachate drain. Refuse was then added in eight one-foot-thick (0.3 m) increments. Each increment was packed to an approximate density of 270 kg/m^3. A description of the refuse in its initial state can be found in Table 1. Refuse was handsorted into the following eleven categories. The eleven chemical analyses listed were performed on each of the eleven refuse categories. The data from the chemical analyses were composited to provide the data shown. The refuse was packed into the lysimeters in its "arrival at landfill" condition. That is, no attempt was made to break up large items or break open any sealed bags. Refuse was added in 8.03-meter-thick increments. Sludges and industrial wastes were layered on the top of each lift (except the first) in proportionate amounts. A one-foot (0.3 m) silty clay layer was placed on top of the refuse and a one-foot (0.3 m) layer of pea gravel was placed on top of the clay. The lids were then bolted, caulked and/or welded shut to provide a watertight and gastight seal. A cross section of a typical cell can be seen in Figure 2.



~400'
~225'
High Bay Pilot Plant
Building Additions
Trailers
Temporary Shed
8 ft. Chain Link Fence
Inside Lysimeter Cells
Prefab Metal Building
T-2
T-1
T-3
Outside Lysimeter Cells
18
19
16
17
(Enlargement)
Lab/Office Wing
N 33°- 41'-25"W 635.97'
S24°-30'-35"W 411.07
Entrance
N
3
6
5
4
2
1
7
8
15
9
10
11
12
13
14
(Enlargement)

Figure 1. Site Plan

These simulated landfills were constructed in 1974 and 1975 and operated until September 1983. Numerous papers have been published on the project design, construction and leachate quality [1,2,3,4,5,6,7]. A final project report is currently in progress[8].

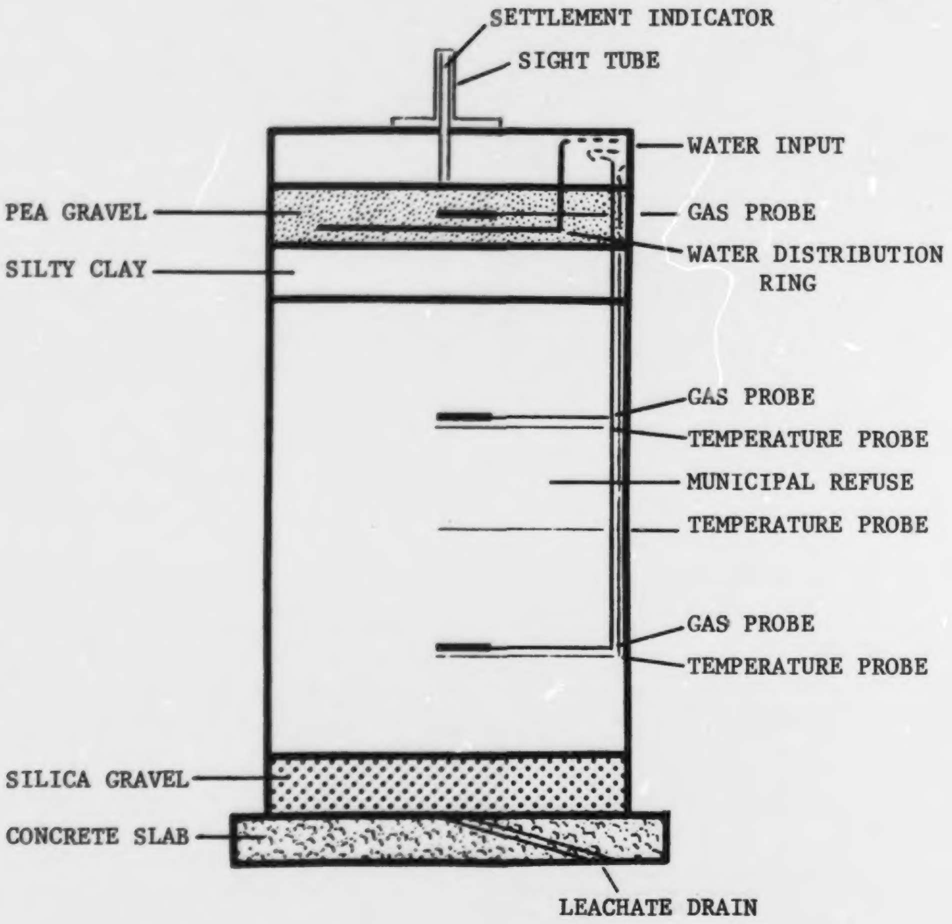
TABLE 1. INITIAL REFUSE DESCRIPTION

Composition of Municipal Refuse
(Percent by wet weight)

Food Waste	8.1 %
Garden Waste	15.7 %
Paper	41.8 %
Plastic, Rubber, Leather	6.9 %
Textiles	4.1 %
Wood	1.8 %
Metal	8.3 %
Glass	7.8 %
Ash, Rock, Dirt	2.9 %
Diapers	2.4 %
Fines	3.2 %

Sort Category Composite
Chemical Analysis of Refuse
(Dry Weight)

COD	520	g/kg
TKN	2.47	g/kg
Total Phosphate	23.2	g/kg
Organic Carbon	218	g/kg
Cadmium	0.240	g/kg
Chromium	1.07	g/kg
Copper	3.16	g/kg
Iron	78.0	g/kg
Nickel	1.01	g/kg
Lead	1.50	g/kg
Zinc	12.7	g/kg


SETTLEMENT INDICATOR
SIGHT TUBE
WATER INPUT
PEA GRAVEL
GAS PROBE
SILTY CLAY
WATER DISTRIBUTION RING
GAS PROBE
TEMPERATURE PROBE
MUNICIPAL REFUSE
TEMPERATURE PROBE
GAS PROBE
TEMPERATURE PROBE
SILICA GRAVEL
CONCRETE SLAB
LEACHATE DRAIN

NOT TO SCALE

Figure 2. Test Cell Cross Section

PURPOSE

The purpose of this lysimeter performance study was to evaluate the physical, chemical and microbiological condition of the 19 simulated landfills at the completion of the 10-year co-disposal project. This study provided the means to physically examine typical municipal landfill components in their in situ state and to analyze the landfill constituents. This also provided an opportunity to examine the effect of co-disposal of industrial sludges with municipal refuse. An additional purpose of this study was to evaluate the performance of the lysimeter tanks and apparatus.

OBJECTIVES

In order to evaluate the simulated landfills thoroughly, specific objectives were established for this project. These objectives were as follows:

1. Perform an in-depth microbiological analysis on the refuse consisting of:

    a) enumeration of total heterotrophic plate count of bacteria, distinguishing between aerobic and anaerobic bacteria,

    b) examination of anaerobic bacteria for methane-producing and Clostridium bacteria,

    c) examination of the refuse for the presence of fungi,

    d) performance of routine indicator analyses: total coliforms; fecal coliforms; fecal streptococci and characterization of a certain percentage of the total number isolated.

2. Determine permeability and specific yield of the refuse.

3. Perform observations on the channeling that occurred through the refuse.

4. Evaluation of the condition of the coal tar epoxy used to line the lysimeters.

5. Evaluation of the seals around the probes and infiltration lines on the lysimeters.

6. Observe and evaluate any layering of the refuse.

7. Analyze the chemical components of the refuse.

8. Analyze the bottom gravel in the test cells in terms of cementation, surface layer deposits and deposits on the gravel.

9. Analyze the leachate from the test cells and compare to the last analysis performed in April 1983 in order to determine if any

noticeable changes occurred over time when no leachate sampling and moisture additions were performed.

10. Dispose of the waste from all test cells. Test cells 9 and 12 were to be handled as hazardous waste with waste disposed of in a secure landfill.

Not all tasks were to be performed on every test cell. Table 2 indicates which tasks were performed on each test cell.

TABLE 2. PROJECT TASK BREAKDOWN

TEST CELL AND CONTENTS	PROCEDURES* 1	2	3	4	5	6	7	8	9	10
1 - Municipal Refuse		2			5			8	9	
2 - Municipal Refuse		2	3	4	5			8	9	
3 - Municipal Refuse	1				5			8	9	
4 - Municipal Refuse		2	3	4	5			8	9	
5 - Municipal Refuse Sewage Sludge					5			8	9	
6 - Municipal Refuse Sewage Sludge					5			8	9	
7 - Municipal Refuse Sewage Sludge	1		3	4	5			8	9	
8 - Municipal Refuse Calcium Carbonate					5			8	9	
9 - Municipal Refuse Petroleum Sludge	1		3	4	5	6	7	8	9	10
10 - Municipal Refuse Battery Production Waste	1		3	4	5	6	7	8	9	
11 - Municipal Refuse Prewetted with Water			3	4	5			8	9	
12 - Municipal Refuse Electroplating Waste	1		3	4	5	6	7	8	9	10
13 - Municipal Refuse Inorganic Pigment Waste	1		3	4	5	6	7	8	9	
14 - Municipal Refuse Chlorine Production Brine Sludge	1		3	4	5	6	7	8	9	
15 - Municipal Refuse Polio Virus					5			8		
16 - Municipal Refuse		2	3	4	5			8	9	
17 - Municipal Refuse Solvent Based Paint Sludge	1		3	4	5	6	7	8	9	
18 - Municipal Refuse	1		3	4	5				9	
19 - Municipal Refuse										

* KEY:
1 - Microbiological
2 - Permeability and Specific Yield
3 - Channeling
4 - Coal Tar Epoxy
5 - Seals
6 - Evaluation of layers of MSW and IW
7 - Sample Analysis of Waste
8 - Gravel Analysis
9 - Leachate Analysis
10 - Hazardous Waste Disposal

SECTION 2

CONCLUSIONS

The following conclusions have been reached as a result of this study:

1. Industrial sludges did not prevent biological decomposition, nor did these sludges eliminate indicator organisms, which were found in all cells.
2. It may not pose any environmental threat to dispose of the specific industrial sludges studied here in sanitary landfills if the relative quantities do not exceed those used here and the sludge is mixed into the municipal refuse.
3. Large numbers of biological pathogens survived the ten-year exposure in the landfill. This suggests that care should be exercised when opening up old landfill sites during construction of recreational facilities or other facilities to be used by large numbers of people.
4. Fecal matter was protected by plastic diapers and plastic bags.
5. Refuse had a permeability of 1.0×10^{-2} to 1.26×10^{-2} cm/sec, which is similar to sands or gravels in absolute value. However, the hydraulic head used was 2.3 to 3.6 times the one-foot head used in laboratory permeability tests.
6. The specific yield of the refuse ranged from 3.20 ft^3/yd^3 in test cell 4 to 6.37 ft^3/yd^3 in test cell 1.
7. Petroleum sludge in cell 9 tended to keep moisture from the refuse. The material that was protected in this manner was dry and not attacked.
8. Petroleum sludge should not be co-disposed with municipal refuse unless some type of wetting agent is added so that the microorganisms can gain access to the material via the water route.
9. There was no channeling of infiltration water through the cell, except when the water was forced around large impervious items, such as automobile tires, bricks, or bagged refuse.
10. The coal tar epoxy linings of the test cells showed no apparent chemical or microbial attack over the length of the ten-year project. The top seals and bottom fiberglass seals were in good condition in most test cells and were watertight, although many were not gas tight. Cell 9

(petroleum waste), cell 10 (battery production waste), cell 11 (prewetted with water), and cell 12 (electroplating waste) all had considerable attack on the bottom fiberglass seals.

11. The seals around the gas and temperature probe connectors, and around the water infiltration lines were cracked on all cells due to age and weather conditions. Gas data generated during this project may not be valid over the total ten-year project period.

12. The effect of chlorine production brine sludge may not have been fully exerted because the sludge was still bagged.

13. There were no distinct layers of refuse within the cells, except for cells 17 and 14. Cell 17 had layers of solvent-based paint sludge and cell 14 had chlorine production brine sludge, which was still in plastic bags clumped in partial layers throughout the cell.

14. Plastic bags protected food wastes and other readily biodegradable materials from decomposition.

15. Paper bags protected food wastes and other readily biodegradable material from decomposition.

16. Protective wrappings were more inhibitory for biodegradation than industrial sludges.

17. Settlement of the refuse was unequal, since considerable material was protected from biological activity.

18. Moisture content affected decomposition. Because of a leak, test cell 15 had the most moisture. It also had the greatest settlement and decomposition.

19. The degree of decomposition was very similar in all cells, except for test cell 15, where large quantities of extraneous water seeped in as a result of the leaking seal.

20. All cells were watertight, except cell 15. Therefore, moisture balances in all cells except cell 15 should be valid.

21. The bottom gravel was in excellent condition in all test cells. There was no cementation of the gravel. There was a small amount of blackish residue on the gravel, which contained from 6 to 27 mg/g COD and from 0 to 0.13 mg/g sulfide.

22. Leachate composition did not change significantly from April 1983, the last month of continuous cell monitoring in the ten-year project, to June 1984, when leachate was collected for a final time as a part of this termination study.

23. The chemical components of the leachate from co-disposal cells did not differ greatly from refuse-only cells.

SECTION 3

RECOMMENDATIONS

As a result of this project, the following recommendations can be made:

1. Plastic and paper bags should be torn open as much as possible to permit readily biodegradable material to decompose. (This is also important for more even settlement of the landfill area.) The usual method of using a bulldozer to perform this task is adequate if layers are kept shallow.

2. Sufficient amounts of water should be permitted in a sanitary landfill to maximize decomposition, as long as leachate quantity is maintained at a level which can either be recycled back to the landfill or treated for discharge.

3. Effects of co-disposal of chlorine production brine sludge with municipal refuse should be studied further to determine the full impact of this type of sludge, since the sludge was still in plastic bags.

4. The microbes present in fecal matter within plastic diapers and plastic bags should be studied further to determine the types and numbers of microbes that may be present and which may cause health problems for sanitary landfill workers exposed to them.

5. A study should be carried out to compare bagged refuse degradation versus unbagged degradation.

6. Similar lysimeter studies should use a silicone or similar sealant on joints and penetrations so they remain flexible throughout the extended times used in landfill studies.

SECTION 4

PROCEDURES

PRELIMINARY PROCEDURES

Shed Construction

A temporary shed (Plate 1) was constructed for containment of the four interior test cells, Nos. 16, 17, 18 and 19, during unloading activities. This shed provided a protected work area and secure storage area for the cells. The containment shed was constructed of 4x4s and 2x4s with plywood sheeting and roof. Its dimensions were 10 ft. x 32 ft. x 20 ft. high with large doors on every side to allow easy access and ventilation.

Plate 1. Shed constructed to house Test Cells 16-19.

Moving Inside Test Cells (Nos. 16 - 19)

Test cells 16, 17, 18 and 19 were moved from their inside location in the Center Hill high bay area to the temporary containment shed before they were unloaded. This procedure involved jacking the cells off their concrete supports to a movable steel platform, using four 10-ton hydraulic jacks. This platform consisted of two 8 ft. x 8 inch deep steel I-beams with a low roller on each end of the beams. The lower lip of the test cell bottom was clamped to the beams at each quarter point.

Each test cell was then pulled on the platform by an electric tow motor forklift to its location in the shed. Two 8-inch channels served as tracks to protect the asphalt parking area.

Inside the shed, the test cell was placed onto concrete blocks, again using the hydraulic jacks. Movement was carried out slowly and carefully in order protect project personnel and prevent damage to the facilities.

SAFETY PROCEDURES

In order to protect both project personnel and employees of the Center Hill Facility from contamination or injury during the waste removal operation, a number of safety procedures were used:

Each worker donned protective clothing which included coveralls, a head cover, boot covers, a pair of latex gloves, a pair of leather or cotton work gloves and a respirator.

All personnel were trained and fitted for the respirators (half and full-faced), necessary to protect their health during removal procedures. These training and fitting services were provided by the Department of Environmental Health, Kettering Laboratory, University of Cincinnati Medical Center.

Each worker received a tetanus shot before working on the project.

A safety manual outlining a complete study safety plan was on hand at the on-site field office. This manual included the names of various personnel to be contacted in case of emergencies, along with their telephone numbers.

A first aid kit and eye wash kit were available at the on-site field office, as well as a fire extinguisher.

Each test cell was filled with water before opening the lids to force out any methane gas that may have been present. This was extremely important for cells with welded lids in order to prevent explosions.

A blower system was set in place at lower levels (below the seven-foot depth) of the test cells to provide sufficient ventilation to the workers.

A pulley system was set up to assist in the removal of a worker from a cell in the event that he became incapacitated while working inside the cell. A ladder was also kept on hand for quick exit from the test cell.

In order to avoid contamination, exposure of the general population to the workers was kept to a minimum as long as the workers wore their contaminated work clothing. Project personnel washed and were fed on-site during the work hours. On-site shower facilities were used and clean clothing donned by workers at the end of each work shift.

TEST CELL CONTENTS REMOVAL

Test Cells in Shed

Test cells 16, 17, 18 and 19 were located in the temporary storage shed. Test cells 16, 18 and 19 contained municipal refuse, while test cell 17 contained municipal refuse and solvent-based paint sludge.

The lids of test cells 16 and 19 had been sealed with a putty sealant, then bolted and welded. To remove this seal, the bolts were removed, the weld was broken with a cutting torch (oxygen and acetylene), and the putty sealant was cut with a shovel. Before breaking the weld seal, the test cell was filled with water to force out any methane gas present which might have presented an explosive hazard.

Test cell 18 had its lid sealed with a putty sealant and bolted. To remove the lid, the bolts were removed and the putty sealant was broken with a shovel. To force out any methane gas, the test cell was filled with water prior to removal of the lid.

The lid of test cell 17 was sealed with a putty sealant, bolted, and welded. A fiberglass well was built around the lid to provide a water seal. This well was removed by cutting it into sections with a saw and prying those sections loose from the top of the test cell. Once this fiberglass well was removed, the procedure was the same as for test cells 16 and 19.

The setup and equipment required for emptying the test cells were as follows. Each worker wore coveralls, a disposable head cover, disposable boot covers, a pair of latex gloves, a pair of leather or cotton work gloves, and a half-mask respirator with all-purpose canisters to prevent breathing of dust particles and organic vapors (if present). Portable steps were placed next to the test cell to be emptied to provide easy access from the ground to the top of the cell. An extension ladder was used to enter the cell once the cell was emptied sufficiently to require such access. Since it would have been very difficult to remove an incapacitated worker from the cell via the extension ladder, a removable beam and pulley system was set up in the shed rafters above the cell opening for emergency worker removal. A blower line was set in the test cell to provide sufficient ventilation while working within the test cell. This was not placed in the test cell until the cell contents were seven feet from the top. The cell contents were removed using a pitchfork, cultivator, shovel, and sometimes hands, and put into 55-gallon plastic garbage cans that were easily transported from the test cells to a garbage dumpster using a forklift with a skid.

Water from the test cells was drained off before starting the removal procedures. The cell was opened by sliding the lid to the top of an adjacent test cell. Once the lid was off, the water infiltration line was cut and the infiltration ring was pulled out of the pea gravel layer. The depth from the top of the test cell to the top of the pea gravel layer was measured. The pea gravel was removed with a shovel and passed in buckets to garbage cans on the forklift skid. As the cans were filled, they were transported to the dumpster for disposal of the contents.

After the pea gravel was removed, another measurement was made from the top of the test cell to the top of the clay layer. The clay layer was removed by shoveling the clay directly into the garbage cans on the forklift skid and transporting the cans to the dumpster for disposal of the contents.

Another measurement was made to determine the depth of refuse prior to removal. To remove the refuse, a plastic garbage can was placed down in the test cell with one or two workers. A pitchfork and cultivator were used to loosen the refuse sufficiently to allow loading into the garbage can. When the can was full, it was lifted to another worker at the top of the cell, where the waste was sorted and placed into another garbage can on the forklift skid. When all plastic garbage cans on the skid were full, the waste was transported by forklift to the dumpster for disposal. Some sorted artifacts were held aside for further analysis. (See Plates 2 - 4)

After the refuse was completely removed, another depth measurement was made to determine the depth to coarse gravel. To remove the coarse gravel, the pulley system was employed. The worker in the cell would fill a bucket with the coarse gravel and pull it up to another worker on top of the cell where it would be dumped into the garbage cans on the forklift skid. Once full, the cans were taken to the dumpster for disposal. When removing the coarse gravel, great care was taken not to damage or plug the drain at the bottom of the test cell.

After the gravel was removed, the test cell was rinsed out to remove the fine sediment on the bottom and to leave the test cell "clean". The lid was replaced on top of the test cell for final closure. One bolt was used to fasten the lids back in place.

Outside Test Cells

Test cells 1 through 15 were located in a cleared area behind the Center Hill Research Facility (see Plate 5). These cells were set in the ground. Test cells 1 through 4 contained municipal refuse, nos. 5 through 7 contained municipal refuse with varying amounts of sewage sludge, no. 8 contained water treatment plant softening sludge, no. 9 contained municipal refuse and petroleum sludge, no. 10 contained municipal refuse and battery production waste sludge, no. 11 contained municipal refuse saturated with water, no. 12 contained municipal refuse and electroplating waste sludge, no. 13 contained

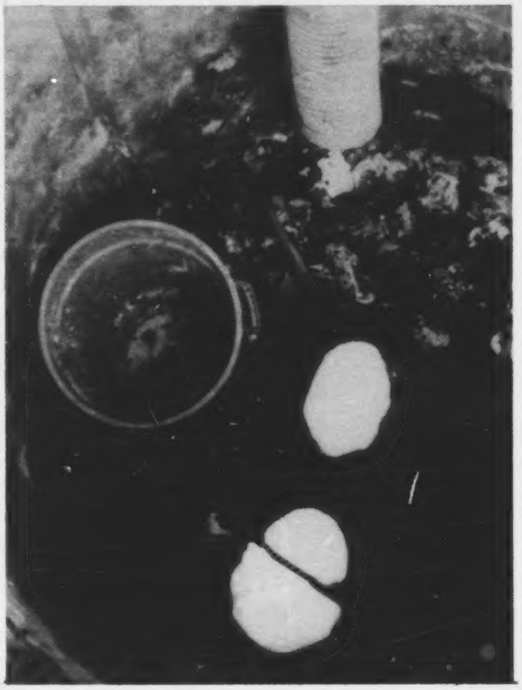


Plate 2. Digging garbage from test cell.

Plate 3. Unloading waste from test cell.

Plate 4. Unloading waste from test cell.

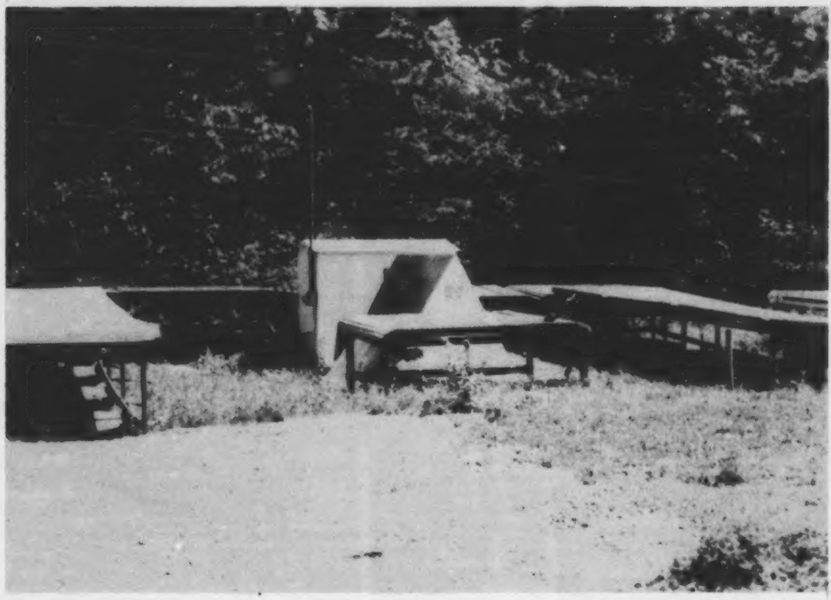


Plate 5. Outside test cells 1-15.

municipal refuse and inorganic pigment waste sludge, no. 14 contained municipal refuse and chlorine production brine sludge, and no. 15 contained municipal refuse with polio virus (this was no longer present during removal procedures). Test cells nos. 9 and 12 were designated hazardous waste cells.

Test cells nos. 1 through 8, 11, and 15 had steel lids that were sealed with a putty sealant and bolted to the main test cell cylinder. The bolts were removed and the putty sealant was broken with a shovel to open these lids.

Test cells nos. 9, 10, 12, 13 and 14 had plywood lids that were bolted to the test cell. When the bolts were removed, the lids slid off easily.

Non-Hazardous Waste Test Cell Procedures (1-8, 10, 11, 13-15)

The general setup and equipment required for removal of the non-hazardous, outside test cell contents were similar to those of the cells located in the containment shed. Workers wore the same protective clothing as described previously. A portable shelter was placed over the test cell opening to protect the cell contents from rain and sun. The removable beam and pulley system was set up on the portable shelter beams above the test cell opening. Since the top of each cell was at ground level, only an extension ladder was required to gain access to the cell. A blower line to provide sufficient ventilation was set up as before. The cell contents were again removed using a pitchfork, cultivator, shovel and hands, and were transported in plastic garbage cans to the dumpster.

Procedures for removing the refuse were as follows for test cells 1-8, 10, 11, and 13-15. The test cell lid was removed and any water left in the cell was drained off. The water infiltration line was cut, and the infiltration ring was pulled from the pea gravel layer. The depth from the top of the test cell to the top of the pea gravel was recorded. The pea gravel was removed with a shovel and spread around the grounds near the top of the test cell. This was done because the area surrounding the cells was very muddy and slippery.

Another measurement was made from the top of the test cell to the clay layer. The clay layer was dug out with a shovel and placed into garbage cans on the outside of the test cell. Two workers then carried the cans to a dumpster where the clay was dumped.

Once the clay was removed, a measurement was made to determine the depth to the refuse at the start of the refuse removal process. To remove the refuse, a garbage can was placed in the test cell with one or two workers. The refuse was dug loose, usually with a pitchfork (sometimes a cultivator was also used), and loaded into the can. The can was lifted to one or two workers stationed at the top of the cell. These workers carried the refuse to the dumpster, where another worker sorted the refuse before final disposal in the dumpster. The sorted artifacts were held aside for further analysis.

After the refuse was completely removed, another depth measurement was made to determine the depth to the coarse gravel layer. To remove the coarse gravel layer, the pulley system was employed. The worker in the cell filled a bucket with the coarse gravel and pulled it up to another one or two workers on top of the cell. These workers carried the can to the dumpster for disposal. When removing the coarse gravel, great care was taken not to damage the drain pipe at the bottom of the test cell. After all the gravel was removed, the test cell was cleared of the equipment used for removal. All cells were rinsed with water after clearing and the lids were replaced on top of the cells for final closure.

The only exception to the procedures for these test cells was for test cell 4. Each can of refuse was weighed before it was sorted and dumped into the dumpster. This was done to determine the total refuse weight for the test cell in order that an in-place density could be determined.

Hazardous Waste Test Cell Procedures

Test cells 9 and 12 contained municipal refuse plus petroleum waste sludge and electroplating waste sludge, respectively. These are designated hazardous waste materials and, therefore, had to be removed, handled, and disposed differently than the other test cell refuse.

These test cells had plywood lids that were bolted to the cell. The bolts were removed and the lids slid off easily. The top layer of pea gravel and clay were removed as in the other test cells. Before and after each layer was removed, a depth measurement was made from the top of the cell to that layer. After the clay was removed, samples of the refuse were taken and sent to CECOS International for analysis and approval to take the waste to their landfill.

In removing the refuse from cells 9 and 12, procedures were the same as those for removing the refuse from the other test cells except that this waste material was packaged into "CECOS Paks" (one-cubic-yard, plastic-lined, corrugated cardboard containers) in preparation for final disposal. The procedures also differed in that workers in the test cell were required to wear full-face masks during removal. Once the waste was removed, the bottom coarse gravel layer was removed in the same manner as for the other test cells. Once the test cells were emptied, they were triple-rinsed in order to leave them "clean" of any hazardous material.

Before issuing approval to take this packaged refuse to the secure chemical landfill, Ohio EPA required the waste to be repackaged into 55-gallon steel drums. This was done in December 1984. Final approval to transport and dispose of the waste came in early January 1985. The drums were sealed tightly and labeled with all proper markings for final disposal, and a manifest was prepared on January 8, 1985. On January 9, 1985, the drums were loaded and transported to the CECOS secure chemical landfill in Clermont County, Ohio, for final disposal.

MICROBIOLOGICAL, CHEMICAL, AND PHYSICAL ANALYSES

Leachate

Leachate was collected by draining all liquid from the cells via the leachate drain pipe located in the bottom of each cell. One-liter cubitainer grab samples were collected for chemical analysis. The volume of the remainder of the leachate was measured, then discarded. Immediately after sampling, the leachate was transported to the University of Cincinnati for analysis. Subsamples for specific analyses were preserved as indicated in the EPA Handbook for Sampling and Sample Preservation of Water and Wastewater and stored at 4°C until the analysis was performed.

Solid Waste for Microbiology

Microbiological samples were taken at three different depths in the refuse for all cells. The exact sampling depth was selected at random for each cell, however, each of the three samples came from within designated ranges within the refuse. The first sample, designated Sample A, was taken between one and three feet from the top of the refuse. The second sample, Sample B, was taken between two and six feet, and the third sample was taken between three and eight feet. Figure 3 depicts the sampling location for each test cell. Exact depths of microbiological samples can be found in Appendix C.

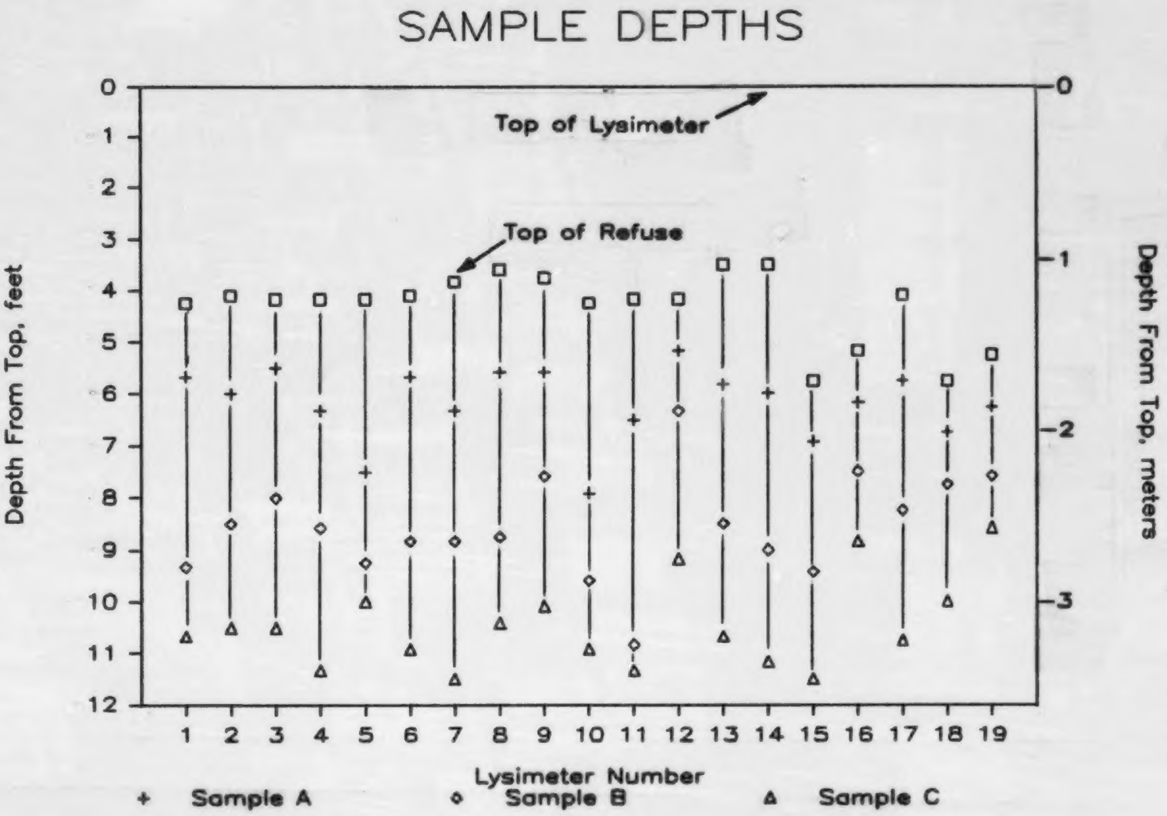


Figure 3. Sample depths for microbiological and chemical analysis samples.

All of the microbiological samples were a composite of five grab samples which were taken at five different locations of the exposed layer. This was accomplished by peeling back the exposed layer of refuse and quickly grabbing a sample. Large items such as bottles, plastic toys, stainless steel pans, etc., were intentionally avoided in the sampling. The total composite samples were approximately 1 kg. As soon as the sample was taken, it was placed in a zip-lock plastic bag with the air squeezed out to decrease the oxygen present. The samples were transported to the University of Cincinnati in coolers where any oxygen remaining in the samples was displaced with nitrogen. The samples consisted largely of leaves, some paper and other decaying organic materials. Disposable diapers were specifically searched for and sampled from many lysimeters in order to analyze the ten-year-old fecal matter. The microbiological samples taken from the diapers consisted only of the fecal matter. All samples were processed within 96 hours. Table 3 indicates the sample types analyzed from each lysimeter. For the remainder of this report, all samples will be referred to by the sample location (i.e. Sample A, Sample B, or Sample C) regardless of the sample type.

TABLE 3. MICROBIOLOGICAL SAMPLE DESCRIPTION

MUNICIPAL REFUSE-ONLY CELLS				INDUSTRIAL REFUSE/ MUNICIPAL REFUSE CELLS			
LYSIMETER NO.	SAMPLE DESIGNATION	SAMPLE LEVEL	SAMPLE DESCRIPTION	LYSIMETER NO.	SAMPLE DESIGNATION	SAMPLE LEVEL	SAMPLE DESCRIPTION
1	A	A	Refuse	9	A	A	Refuse
	B	B	Refuse		B	B	Refuse
	C	C	Refuse		C	C	Refuse
3	A	A	Refuse	10	A	A	Refuse
	D	B	Diaper		B	B	Refuse
	C	C	Refuse		C	C	Refuse
7	A	A	Refuse	12	A	A	Refuse
	B	B	Refuse		B	B	Refuse
	C	C	Refuse		C	C	Refuse
16	A	A	Refuse	13	D	A	Diaper
	D	B	Diaper		B	B	Refuse
	B	B	Refuse		C	C	Refuse
18	A	A	Refuse	14	A	A	Refuse
	D1	B	Diaper		B	B	Refuse
	D2	B	Diaper		C	C	Refuse
19	D	A	Diaper	17	A	A	Refuse
	B	B	Refuse		D1	B	Diaper
	-	C	No Sample		D2	C	Diaper

Solid Waste for Chemical Analysis

The solid waste samples taken for chemical analyses were also taken at three different depths in the refuse. The exact sampling depths were the same as for the microbiological samples. Again the first sample, designated Sample A, was taken between one and three feet from the top of the refuse. The second sample, Sample B, was taken between two and six feet, and the third sample was taken between three and eight feet. Figure 3 depicts the sampling location for each test cell. Exact depths of these samples can be found in Appendix C.

The routine solid waste samples were composite samples taken from the entire surface of the depth being sampled. The sample was representative of of all refuse found at the given layer and, therefore, included large items such as glass bottles, cans, plastic items, etc. as well as decaying organic matter. Approximately 50 pounds or one half to two thirds of a 55-gallon garbage can was collected. This entire sample, exactly as sampled from the lysimeter, was placed on a drying pan and dried at 75°C until the refuse reached constant weight. The percent moisture was determined on the "as is" sample. After drying, the refuse was coarsely ground, followed by fine grinding. A subsample of the thoroughly mixed, finely ground sample was again dried at 75°C to drive off any remaining moisture so that the overall percent moisture could be determined. All analyses are reported in terms of wet weight and in terms of dry weight based on the overall percent moisture.

Gravel

The bottom gravel was left in place until all of the refuse was removed from the cell. When the entire gravel/refuse interface was exposed, visual observations were made and recorded. Actual samples were collected after removing the top three to four inches of gravel. This was done to make sure the samples were not taken from the refuse/gravel interface area. A composite sample of the exposed gravel was taken and placed in two one-gallon, zip-lock bags. The samples were then transported to the University of Cincinnati for analysis.

METHODS

Microbiology

Biological Safety Hoods

Baker Biogard Hood. The Baker Biogard Hood was used to transfer fungal cultures. This was necessary as pathogenic fungi have been found in solid waste (Donnelly and Scarpino, 1984) and because fungi (whether pathogenic or not) may cause allergies in individuals who inhale fungal spores. Therefore, it was important to use the biological safety hood for all fungal transfers. The Baker Biogard Hood which was used, a Class II, Type 1 (manufactured by the Baker Co., Biddeford, Maine), was designed to reduce and eliminate airborne particles which could infect personnel and contaminate desks and glassware in the immediate area. It contains a Hepa filter designed to remove 99.97% of the particles having an average diameter of 0.34 µm.

Anaerobic Safety Hood. The second unit was a stainless steel cabinet (with outside measurements of 60 x 92 x 46 cm, making a final volume of 0.25 m^3). The unit contained several gas port holes, two rubber gloves, a viewing glass, rubber sealed pressure doors, and a pressure gauge. During use, nitrogen gas was placed inside the cabinet to decrease the effect of oxygen on the solid waste sample. Within the hood, each sample was weighed and homogenized with a Waring blender. Then the homogenized sample was allowed to sit for one-half hour to give atomized water droplets time to condense. Before opening the cabinet door, the air was forced out through a Hepa filter with a vacuum pump to decrease the danger of workers inhaling the water droplets containing pathogenic microorganisms.

Sample Homogenization and Diluents

For microbial studies, forty grams of solid waste were placed in the

Waring blender jar together with 360 ml of sterile 0.1% peptone water (Standard Methods, 1981) to make a 1:10 dilution. For tests involving pH and conductivity, distilled water replaced the peptone water as a diluent. The Waring blender jar containing the waste and diluent was placed in the anaerobic hood where the air was evacuated and replaced by nitrogen gas. Then the sample was homogenized in the Waring blender at high speed for 15 seconds. It was allowed to sit for 30 minutes to allow the water droplets to condense. Then the hood was evacuated to force the air through the Hepa filter and remove any contaminated water droplets still remaining in the cabinet air. Following this, the waste samples were diluted with 0.1% peptone water in preparation for the enumeration process. The samples for pH and conductivity were not further diluted.

Anaerobic Cultivation Techniques

All plates used for anaerobic studies (blood, Standard Methods, and egg yolk agars) were pre-reduced with carbon dioxide gas in a box for at least two hours. Following the inoculation, these plates were returned to the carbon dioxide gas chamber in the upright position for one-half hour to allow the inoculum to seep down into the agar. Then they were turned over and placed in a BBL GasPak (BBL) jar for 24 to 48 hours. All GasPak (BBL) jars were made anaerobic with disposable BBL hydrogen-carbon dioxide generator envelopes.

When tubed media were to be incubated anaerobically, they were first heated in a boiling water bath for ten minutes and cooled. Following the tube inoculation, sterile mineral oil was placed on the media surface to the height of at least one centimeter. The tubes then were incubated aerobically. If there were a reason for not placing mineral oil on the media surface, then the tubes were incubated in the GasPak jar as described above.

Culture Storage

Isolated microorganisms were kept in special media until they could be identified. Otherwise, they might have died out within a week at room temperature. The gram negative rods and streptococci were grown on heart infusion agar for 48 hours at 35°C. The clostridia were also grown for 48 hours at 35°C, but on chopped meat medium or thioglycollate 135C medium (under oil). The fungi were grown for one week at room temperature on Sabouraud agar slants. These cultures were then stored at room temperature (23°C).

Microbiological Enumeration Procedures

Total and Fecal Coliforms (Standard Methods - 909). Total coliforms and fecal coliforms were determined by the most probable number (MPN) procedures as described in the above reference. Ten to 10^{-5} ml of the diluted homogenized sample were inoculated into five tubes per dilution of lauryl sulfate broth. Following a 48-hour incubation at 35°C, two drops of all positive tubes were inoculated into brilliant green bile broth and EC tubes. All media were incubated as indicated in Standard Methods (1981). The completed test was carried out for all positive tubes in all samples. To determine the results, the number of positive tubes were converted to the MPN values by the Standard Methods (1976) MPN Index table.

Fecal Streptococci (Standard Methods - 910). Five tubes per dilution of azide dextrose were inoculated with 1.0 to 10^{-5} ml of homogenized sample. Following the 48-hour incubation of azide dextrose tubes, all positive tubes were streaked on to PSE agar. The confirmed test was done as described in Standard Methods. To arrive at the final streptococcal concentration, the number of positive tubes were converted to the MPN values by the Standard Methods (1976) MPN Index.

Clostridium Perfringens (Koneman et al, 1979; Dowell and Hawkins, 1976). Stormy fermentation of iron milk was used as an MPN fecal indicator test to determine the concentration of anaerobes and especially of *Clostridium perfringens* in solid waste (Donnelly and Scarpino, 1984). The medium chosen was iron skim milk (Bonde, 1963; and Dowell and Hawkins, 1976). This was a five-tube test to which 1.0 to 10^{-5} ml of diluted inoculum was added. Following the addition of the samples, one centimeter of sterile mineral oil was added aseptically to each tube. Then the tubes were incubated at 35°C for 48 hours and read for coagulation and gas production. To confirm the presence of *Clostridium perfringens*, ten to twenty percent of the tubes per sample were streaked on blood agar plates and examined for the presence of double-zone hemolysis. This test signals the presence of *C. perfringens*. Most of these isolates were identified by the API-20A procedure.

Plate Count Procedures. All plate counts were made by the spread plate technique. In preparation for plating, the diluted sample tubes were mixed by the vortex mixer. Then 0.1 ml portions from each dilution were placed on duplicate plates and spread with a sterile bent glass rod (Bordner et al, 1979, and Koch, 1981). Following the inoculation, a one-half-hour incubation period at room temperature was included to give the inoculum time to sink into the agar media. Then the plates were inverted and incubated at 35°C. The anaerobic plates were kept in a carbon dioxide chamber during this one-half-hour period prior to being placed in a GasPak jar for incubation. The plates with their incubation periods are listed in Table 4.

Total Plate Counts. Total plate counts were done on Standard Methods agar. After the plates were inoculated with diluted samples, they were incubated both aerobically and anaerobically to give some measure of the aerobic and anaerobic bacterial counts.

Clostridium. Tryptone sulfite cycloserine agar (Duncan and Harmon, 1976) was used to give the *Clostridium perfringens* plate counts and serve as a source of *Clostridium* isolates for identification purposes. Growth on the medium, colony types, and various agar reactions suggest the presence of the following clostridia: positive lecithinase, *C. perfringens*, and *C. novyi*; positive lipase, *C. novyi* and *C. botulinum*; and the presence of neither of the two reactions together with a certain colony type may suggest *C. tetani* (Koneman et al., 1983).

Fungi. All fungi, including both yeasts and molds, were enumerated on rose bengal agar. This media and the procedure for its use are given in

TABLE 4. MEDIA AND INCUBATION CONDITIONS

TYPE OF MEDIUM	TYPE OF MICROORGANISM SELECTED
MPN Test Broths/Agar	
Lauryl sulfate[a]	Total coliform and fecal coliform
Brilliant green bile[a]	Total coliform
EC[b]	Fecal coliform
Azide dextrose[a]	Fecal *streptoccus*
PSE[b]	Fecal *streptoccus*
Iron milk	*Clostridium perfringens*
Enrichment Broths	
Methanogenesis[c]	Methane bacteria
Cellulose digestion[d]	Molds
Enumeration Agars	
Standard Methods - aerobic[a]	Total plate counts - aerobic
anaerobic[a]	Total plate counts - anaerobic
MacConkey[b]	Gram negative rods
KF[a]	Fecal *streptococcus*
Tryptone sulfite cycloserine[a]	*Clostridium perfringens*
Rose bengal[e]	*Fungi*

a = 35°C, 48 hours
b = 35°C, 24 hours
c = 35°C, one month
d = room temperature, one month
e = room temperature, one week

Standard Methods (1981).

Gram Negative Rods. MacConkey agar was used to determine the gram negative rod plate counts. Following the sample inoculation, the plates were incubated for 24 hours and counted. Then the plates were incubated again for another 24 hours to allow the slow-growing varieties to produce visible colonies. These were selected for identification together with the fast-growing variety which grew at 24 hours (Scarpino, 1984). It was noted previously that gram negative rod mucoid colonies were frequently so large that at 48 hours they obscured nearby colonies, so colonial growth numbers at 24 hours were used instead.

Streptococci. KF streptococcal agar and sometimes m-enterococcus agar were used to determine the plate counts of streptococci. However, for the isolation of streptococcal colonies for identification purposes, only the KF streptococcal agar was used.

Additional Microbial Analyses

Methane-Producing Bacteria. A methanogenesis medium was used to detect methane gas (Donnelly and Scarpino, 1984). The inoculum added to this medium consisted of five grams of solid waste or 5.0 to 10^{-3} ml of diluted homogenized waste. Then the Escherichia coli inoculum and $NaHCO_3$ described in Appendix B were also added at this time. Following the addition of these agents, the vials were flushed with carbon dioxide gas and incubated at 35°C for three days. One vial per dilution was used.

The E. coli was added to metabolize the food materials and use up the oxygen. With the oxygen greatly reduced, hydrogen gas was added to the vials. This was done in the following manner: with a 50 ml syringe, 30 ml of the carbon dioxide from each vial were removed and 30 ml of hydrogen were added to give a 30:70 hydrogen:carbon dioxide ratio. The incubation was carried on at 35°C for one to two months.

The gases in the vials were measured by a Perkin-Elmer 900 gas chromatograph. For the analysis, up to 3 ml volumes of sample gas were compared to the same volume of a standard gas. The standard gas used was from Matheson Gas Co. (Dayton, Ohio) and contained 16.47% N_2, 4.15% O_2, 34.71% CO_2, and 44.67% CH_4. The analysis was normalized for 100% based on the occurrence of CH_4, CO_2, O_2 and N_2 in the sample (McNair and Bonelli, 1969). A computer program was used for individual sample calculations.

Cellulose Digestion. The cellulose digestion medium described by Cooke (1970) was used for this study with some adaptations. Originally Cooke used short incubation periods up to 18 days at 30°C and tested the digestion of cellulose by measuring the change in tensile strength of cloth strips. We had no comparable instruments to make these comparisons. Instead, the digestion of Whatman #1 filter paper was used. Strips were placed in tubes containing 10 ml of Cook's medium. He stressed the use of aluminum tops on the tubes, undoubtably to allow an adequate amount of air for the mold growth, so these were used in this study. The molds were inoculated at the air-liquid medium line and incubated at room temperature for at least one month. The endpoint of the test was the obvious degradation of the filter paper. This occured most generally at the air:medium line. However, light or thin places in the paper were seen when the tubes were held up to the light, and pin holes were also present. Growth occurred above and below the medium. In some tubes, spore production was present along with growth in concentric rings.

Microbial Identification Procedures

Isolation of Pure Cultures. Clostridial, fungal, gram-negative rods and streptococcal isolates came from the enumeration agar plates described above.

They were streaked for pure culture isolation according to definitely prescribed procedures (Donnelly and Scarpino, 1984). Microorganisms from solid waste are usually stressed, which means that some species grow out very slowly, while others may not be so stressed and grow out in large numbers. Even in this study, many so-called isolates contained slow-growing contaminates. So it was important to adhere to the isolating procedures. These procedures were carried out at 35°C unless otherwise stated. Clostridial cultures were streaked twice on egg yolk agar and once on blood agar plates. Sometimes it was necessary to streak a second blood plate. The fungi were streaked once on Sabouraud potato dextrose, mycosel or inhibitory mold agars and incubated at room temperature for a week or two. The gram-negative rods were streaked twice on heart infusion agar, left overnight at room temperature and streaked again on heart infusion agar. Streptococci were streaked twice on heart infusion agar, once on TTC agar (2,3,5 Triphenyl tetrazolium chloride), tellurite agar (if not inhibited), and again on heart infusion agar.

Test Procedures:

- 0.04% Potassium tellurite on brain heart infusion agar
  - Test Conditions: Incubated inoculated plate at 35°C for seven days.
  - Test Results: The appearance of black colonial growth indicated tellurite hydrolysis reaction.
- TTC Agar (2,3,5-Triphenyl tetrazolium chloride) (Bordner et al., 1978)
  - Test Conditions: Inoculated plate and incubated at 35°C for 48 hours.
  - Test Results: The appearance of pink colonies indicated tetrazolium reduction.

Clostridium. Pure cultures of Clostridium were identified by the API-20A technique. In addition, hemolysis reactions and lipase and lecithinase reactions were used as diagnostic aids.

Test Procedures:

- API 20A (Analytab Products, Inc.)
- Gram Stain (Std. Methods), 1976; Soc. for Am. Bacteriologists, 1957)
- Hemolysis (Koneman et al., 1979; Cowan, 1974; Bordner et al., 1978)
  - Test Conditions: Clostridium perfringens, inoculated blood agar plate incubated in a Gas Pak (BL)) at 35°C for 48 hours. Streptococcus blood agar plates incubated at 35°C for 48 hours.
  - Test Results: Clostridium perfringens produced target zone hemolysis which is a double zone one to two centimeters in diameter. For streptococci, see Bordner et al. (1978).
- Lecithinase Production (Koneman et al., 1979)
  - Test Conditions: Incubated egg yolk plates in a Gas Pak (BBL) jar at 35°C for 24 hours.
  - Test Results: The lecithinase reaction, a large, yellow zone of precipitation, extended from the Clostridium perfringens colony 0.5 to 1 cm.
- Lipase Production (Koneman et al., 1979)
  - Test Conditions: Same as for lecithinase production.

Test Results: A shining, irridescent reaction on the surface of the egg yolk plate. The diameter was 0.2 to 0.5 cm.

Fungi. All fungal types were identified. They were isolated on the various media listed above and, in particular, on the Sabouraud agar. Various media were used to encourage the spore production so necessary to fungal identification. Yeast were occasionally grown on eosine methylene blue to facilitate the germ tube production.

The fungal identifications were made by microscopic examination using slide and tape procedures. The fungal growth was dyed with lactophenyl cotton blue. When dimorphic fungi were suspected, the cultures were inoculated repeatedly on Karung's medium (Karung and Yegim, 1954). References were made to the following texts: Emmons et al. (1977); Rippon (1974); Finegold et al. (1978); Koneman et al. (1978, 1983); Lennette et al. (1980); Campbell and Steward (1980); and Cooke (1963). Not all of the genera could be identified because of the lack of spore production.

Test Procedures:

- Capsules, *Cryptococcus neoformans* (Finegold et al, 1978; Silva-Hutner & Cooper, *1980*)
  - Test Conditions: Placed culture and India ink on slide. Added a cover slip and examined microscopically.
  - Test Results: *Cryptococcus neoformans* cultures showed round budding cells *with capsules*.
- *Chlamydospores*, *Candida albicans* (Koneman et al., 1978)
  - Test Conditions: Grew *Candida*-like colonies on cornmeal agar at room temperature for 48 hours.
  - Test Results: *Candida albicans* produced chlamydospores
- Test for Dimorphic Molds (Schwartz, January 1979. Personal communication; Karung and Yegum, 1954)
  - Test Conditions: Inoculated Karung's medium and incubated at 35°C up to two weeks.
  - Test Results: Mold-like colonies converted to yeast form.
- Germ Tube Test for *Candida albicans* (Campbell and Stewart, 1982)
  - Test Conditions: Inoculated eosin methylene blue agar (Difco) plate yeast culture. Incubated at 35°C for 24 hours. Examined microscopically.
  - Test Results: *Candida albicans* will produce a germ tube extending from the yeast cell.

Gram-Negative Bacteria. Isolates were taken from the MacConkey agar plates. They were identified by the API-20E procedure. Often additional tests were required such as the oxidase reaction, motility, and the oxidation-fermentation test.

Test Procedures:

- API 20E (Analytab Products, Inc.)
- Gram Stain (*Std. Methods*, 1976; Soc. for Am. Bacteriologists, 1957)
- Indole Test (*Standard Methods*, 1976)
- Motility Test (Bordner et al., 1978)
- Oxidase Reaction (Bordner et al., 1978)

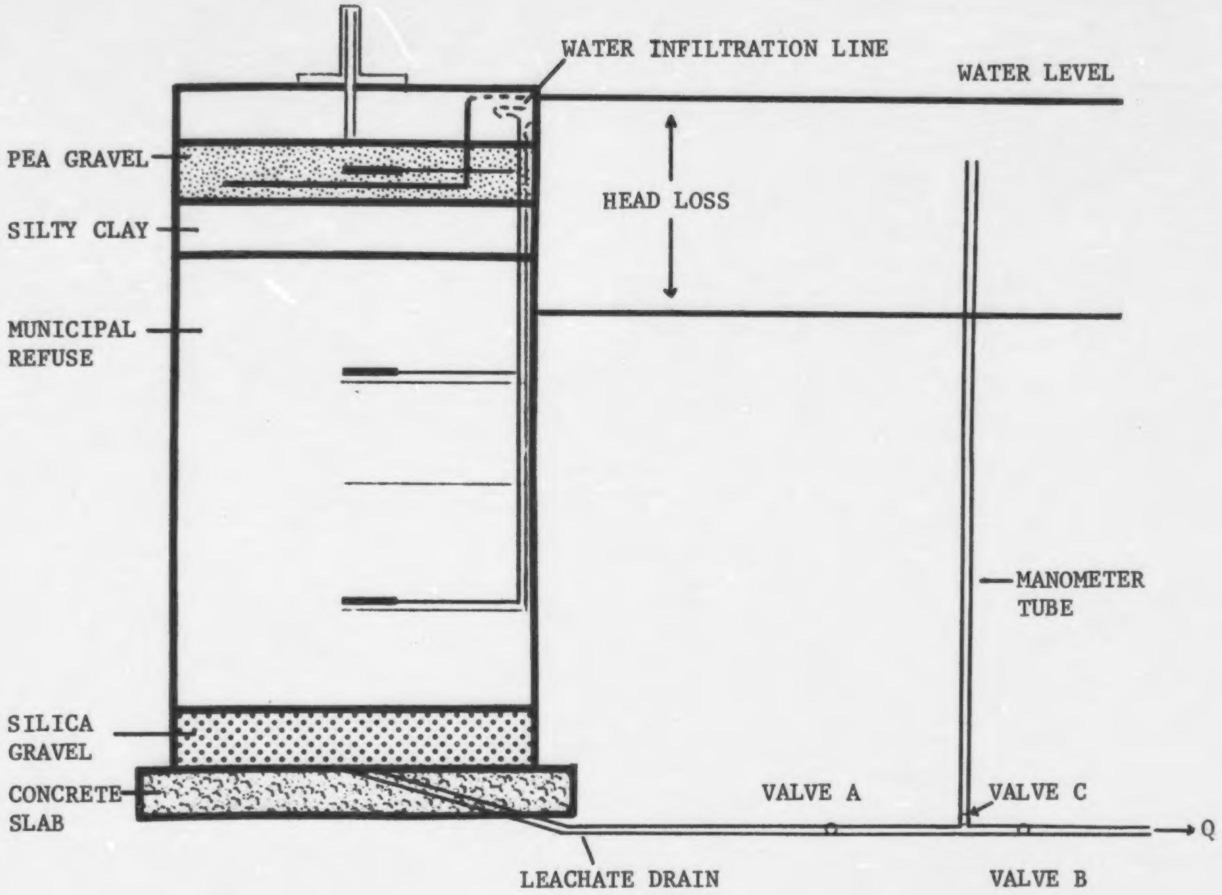
- Oxidation-Fermentation Test (Cowan, 1974; Fineburg et al., 1978)
  For gram-negative rods.
  Test Conditions: Inoculated two tubes (heated in boiling water for ten minutes and cooled). Overlaid one tube with mineral oil to a height of 0.5 cm. Incubated at 35°C for five days.
  Test Results: The fermentation reaction produced acid (tube turned from green to yellow) in the anaerobic tube. The oxidation reaction produced acid in both the aerobic and the anaerobic tube. The third alternative, a negative reaction, had no reaction in either tube.

Streptococcus. The streptococci were taken from the Kf Streptococcal agar plates. They were identified by the procedures described in Bergy's manual (1974). The media used were those described by Bordner et al. (1979).

Test Procedures:
- Catalase Test (Bordner et al., 1978)
- Dihydrolase Test for Arginine (Bordner et al., 1978; MacFaddin, 1976)
  Test Conditions: Inoculated freshly prepared (or heated in boiling water for ten minutes and cooled) decarboxylase test medium containing arginine. Overlaid each tube with 0.5 cm of sterile mineral oil. Incubated at 35°C for four days.
  Test Results: A positive result showed a change from straw-colored media to a rose-red color, indicating the presence of arginine dihydrolase.
- Gram Stain (*Std. Methods*, 1976; Soc. for Am. Bacteriologists, 1957)
- pH 9.6 in Brain Heart Infusion Broth (Bordner et al., 1978)
- Sodium Hipporate Hydrolysis Test (Facklam et al., 1974)
  Test Conditions: Centrifuged a 48-hour hipporate broth culture. Placed 0.8 ml of the supernatant to a clean tube. Added 0.2 ml of ferric chloride reagent.
  Test Results: If a heavy precipitate remained longer than ten minutes, then the test was positive.
- Temperature, Growth at 10°C (Bordner et al., 1978)
  Test Conditions: Inoculated a 24-hour culture of Streptococcus in heart infusion broth by adding one drop to a tube of brain heart infusion broth. Incubated the tube at 10°C for five days.
  Test Results: Growth.
- Temperature, Growth at 45°C (Bordner et al., 1978)
  Test Conditions: From a 24-hour culture (35°C) of Streptococcus in heart infusion broth, inoculated one drop into a tube of brain heart infusion broth. Incubated at 35°C for 48 hours.
  Test Results: Growth.

Permeability

Constant head permeability measurements of the lysimeter contents were made by fitting the lysimeters with a temporary unit attached to the existing leachate drain pipe (Figure 4). The unit consisted of variable length 3/4-inch PVC pipe with a 12-foot glass manometer tube attached at 90° in


WATER INFILTRATION LINE
WATER LEVEL
PEA GRAVEL
SILTY CLAY
HEAD LOSS
MUNICIPAL REFUSE
MANOMETER TUBE
SILICA GRAVEL
CONCRETE SLAB
VALVE A
VALVE C
Q
LEACHATE DRAIN
VALVE B

NOT TO SCALE

Figure 4. Setup for permeability measurement.

the middle of the pipe. Shutoff valves were placed on both sides of the manometer tube and on the base of the tube itself. A wooden frame was built to support the 12-foot manometer tube. Because of the temporary nature of the setup, it was easily moved from cell to cell to perform the measurements. A rubber hose with a water meter controlled hydraulic flow during the permeability measurements. A drainpipe was fitted into the existing water input connector so that a constant head was maintained.

In order to perform the permeability measurement, the lysimeter lid was opened as described earlier, and the pea gravel was removed. The temporary measurement unit and the drainpipe were then installed. Valves A and B were opened, followed by Valve C. Water was run slowly into the cell from the bottom at Valve B until the water level reached the top of the lysimeter. This had the effect of removing any trapped gas from the cell as the water exited through the top drainpipe. Valves A and B were then closed. The water source at Valve B was disconnected and placed into the top of the lysimeter. The water was slowly turned on to maintain a constant head. All valves were then opened. The water flow was maintained at the top of the lysimeter by adjusting flow up or down as necessary. When the level in the manometer tube reached its lowest elevation, the difference in the level of the water surface and the manometer miniscus, i, was recorded. Flow rate, Q, was measured over a five-minute period and over a ten-minute period. No difference was noted for either.

The coefficient of permeability was calculated according to the following equation:

$$K = \frac{Q}{iA}$$

where: K = Coefficient of permeability, ft/sec
Q = Rate of flow, ft^3/sec
A = Cross-sectional area of refuse through which flow has taken place, ft^2
i = Head loss of gradient over a given flow distance, ft/ft

Specific Yield

Specific yield was determined after the permeability tests. The water level was raised very slowly to the top of the refuse. Valves A, B and C were closed. Leachate collection containers were readied for yield. At "time zero", valves A and B were opened. The total volume of leachate was measured from "time zero" until all leaching stopped. This provided the information to determine the specific yield of the refuse. It was also felt that determining the rate at which the leachate flowed from the refuse would be potentially useful for design of leachate collection pumping and treatment systems for municipal landfills. This type of information may not be readily available, but is easily obtained in a controlled lysimeter study. The volume of leachate obtained with respect to time was measured in three stages designated as "short-term leachate production", "long term leachate production", and "total leachate volume". Short-term refers to the leachate that flowed out very rapidly because of saturated conditions and some hydraulic head (six to seven feet). This short-term flow gave a large volume in a matter of hours. When the head was decreased and most of the pore leachate drained out, the flow decreased to a drip rate of a few milliliters per minute. This dripping was very regular and continued over a long period of time. The leachate collected during this period was defined as the long-term leachate production. In some cases the leachate continued to drip very slowly (a few drips per minute) for several days. Only when the dripping completely stopped was the total volume calculated.

The specific yield was calculated according to the following equation:

$$Y_T = \frac{Q}{V}$$

where: Y_T = total specific yield, ft^3/yd^3
Q = total volume of leachate, L (corrected to ft^3)
V = refuse volume, yd^3

The leachate production volumes and times were determined and the rate at which the leachate flowed from the lysimeter in terms of the volume of refuse was calculated according to the following equation:

$$LP = \frac{\frac{Q}{T}}{V}$$

where: LP = leachate production, $ft^3/hr/yd^3$
Q = volume of leachate, L (corrected to ft^3)
T = time to accumulate Q, hr
V = refuse volume, yd^3

Channeling Evaluation Procedure

Channeling of water around the refuse was evaluated by visual observation and moisture content determination. No evidence of channeling was noted except where the petroleum sludge in test cell 9 kept moisture from some of the material in that test cell. Moisture content determinations were made in each of the three refuse samples from all test cells. Each sample was weighed and dried at 75°C to constant weight. Moisture contents were observed to be fairly uniform throughout the test cells. Sufficient moisture appeared to be present in all the cells for good biological activity. Test cells 1 and 9 appeared to be less wet than the others, and this was found to be true from the moisture determination. Test cells 4 and 15 appeared to be more wet than the others, and this was found to be true from the moisture determination. Refuse in test cell 11 was wetted prior to original cell loading and had the second highest moisture content from the moisture content analyses.

Seals and Coal Tar Epoxy Condition

Top Seals. The top seals around the lid and the site glass were examined for leaks and cracks. These were then photographed. Seals and the infiltration line, gas lines, and temperature probes were also examined and photographed. Tests were run on the infiltration line valves to see if they would leak water. It was assumed that if they leaked water, they would also leak gas.

Coal Tar Epoxy. The lining of each test cell was examined for attack on the coal tar epoxy by the refuse or decomposition products. Generally, any attack or any other condition that needed to be reported was noted. The lining was photographed in most cells to document condition.

Bottom Seals. The bottom fiber glass seal was examined in each case where there was this type of seal. Some of the cells (the four interior cells) had a painted steel bottom. Generally, those conditions which appeared important were noted. Such things as overall condition, water seal, bond between the fiber glass and concrete or steel and texture were reported. These seals were also photographed.

Procedures for Evaluation of MSW and IW Condition

Evaluation of the condition of the MSW only and MSW/IW combined refuse was carried out by several methods and procedures. Visual observation and identification were used to determine the state of degradation of individual items or artifacts in the test cells. This included comparisons between artifacts as to whether they were wet or dry and whether they had undergone little attack or severe attack in the landfill environment. The fact that an item was identifiable after ten years meant, as a minimum, that total decomposition had not taken place. Artifacts were segregated and examined individually and collectively from the individual cells. Artifacts were photographed in black and white and in color.

Bags of refuse that had been sealed for ten years were opened and the contents individually examined by hand picking and separating. Observations were made as to the moisture, overall condition, degree of protection provided by the packaging, strength of fiber for clothes, ability to read printed pages, resistance to attack of dyes, paints, and specific materials of construction, for example, plastic or rubber. Evaluation was made as to whether the artifact was still in a usable state or not. Attempts were made to answer the question of why the artifact was still intact after ten years.

Presence or absence and condition of the IW sludges were noted. These were examined, if found, to determine if they had undergone decomposition. Artifacts immediately adjacent to the sludges were examined to see what effect, if any, the sludge had on the decomposition process. Such physical features as sludge condition, layering, moisture, ability to identify the sludge in the refuse mass, odor, and color were noted.

Packaging and type were noted, since the packaging may have caused the artifact to be in the particular state or condition observed. Photographs were taken in black and white and color to document the conditions noted.

Artifacts were preserved for additional tests and evaluation. For example, copper pennies were found in various states of attack. These were all weighed and compared with a new penny to see if they had lost or gained weight. It was hoped that such a procedure would lead to a model and better understanding of the decomposition process of the heavy metal copper in the landfill environment.

Physical, chemical and microbiological analyses were carried out and samples taken from three general locations in the refuse mass: top, center, and bottom. Each depth was noted. An absolute depth was not selected in advance because of the differences in settling in the individual test cells.

Evaluation of Layers of MSW and IW

Layers of MSW only and combined MSW and IW were evaluated by observation and chemical analysis of the mixtures. Attempts were made to study the layers, but only in a couple of instances was it possible to isolate specific layers. Layers of chlorine production brine sludge were readily noted, because the waste sludge was still bagged. Layers of paint sludge were noted because of the total apparent lack of decomposition of the six-inch to nine-inch layers of solvent-based paint sludge. Generally, all of the other sludges were so intermingled with MSW that it was not possible to physically locate a layer and excavate around it for pictures and other evaluations.

Samples of the MSW and combined MSW and IW were subjected to moisture content determination, coarse grinding and fine grinding before chemical analysis. Analyses for COD, TKN, Cr, Cu, Pb, Ni, Cd, Fe, Zn and moisture content were carried out on the co-disposal cells only. Results were compared to evaluate differences in the chemical composition of the layers in the different test cells.

Analysis of Waste Materials

Analyses of the finely ground solid waste were performed according to established methods. The exact methods used and all exceptions are described below. All samples were obtained as grab samples from the thoroughly mixed, finely ground bulk sample.

- Percent Moisture:
  Moisture content was determined on the bulk refuse sample in its "as sampled" condition and on a four-to-five-gram sample after the fine grinding. In both cases, weighed samples were brought to constant weight in a 75°C oven. The drying procedure took a minimum of two days and usually took three days.

- COD (Chemical Oxygen Demand): Standard Methods - 508
  20 mg. samples were weighed and used for the analysis.

- TOC (Total Organic Carbon): Overburdens and Minesoils - 3.2.14
  The residue from the percent moisture determination performed on the four-to-five-gram finely ground samples was used to gravimetrically determine the total organic carbon. Samples were placed in a 200°C furnace for one-half hour. The temperature was raised 50°C every half hour to a maximum temperature of 550°C. This was necessary to keep the waste samples from igniting.

- TKN (Total Kjeldahl Nitrogen): Standard Methods - 421
  Samples of approximately 500 mg. were weighed and used for the analysis.

- Chloride: Compilation of Methods for Measuring Pollution Parameters in Sanitary Landfill Leachates - 8.1
  Samples of approximately one gram were weighed and mixed with 50 mls of H_2O. This paste was then digested by a H_2SO_4/H_2O mixture. After refluxing for 25 minutes, the samples were cooled to approximately 40-50°C, the pH was adjusted to >8, and the samples were filtered through a glass fiber filter. The mercuric nitrate titration was performed on the filtrate as in the stated reference.

- pH
  pH was measured on the solid waste paste that was created as the first step of the chloride procedure.

Gravel

Gravel residue was separated from the gravel by a rinsing procedure. This was accomplished by filling a 250 ml pre-weighed nalgene bottle with the wet gravel. This was then nearly filled with deionized H_2O and agitated to remove the residue from the gravel. The H_2O was decanted into a 250 ml volumetric flask. Each piece of gravel was then rinsed individually into the volumetric flask. Finally, the plastic bottle was rinsed into the flask, and the volume was brought to 250 ml. This liquid was then used for both the COD and sulfide analysis. The gravel was dried in a 103-105°C oven to establish a dry weight for the gravel. The difference in the wet weight and dry weight of the gravel was considered the wet residue weight.

- Sulfide: Hach Method
  A semi-quantitative sulfide method was used to estimate sulfide levels in the gravel residue. 250 ml nalgene bottles with screw-type lids were fitted with rubber gaskets to hold a piece of lead acetate saturated filter paper and to provide a tight seal. A three-millimeter hole was drilled in the center of the lid to allow gases to escape. One hundred milliliters of sample were acidified in the bottle by adding one half of an alka-seltzer tablet and one milliliter of HCl. The lid was immediately placed on the bottle and left for one-half hour. All sulfide in the sample was converted to H_2S upon acidification and then converted to PbS when passing through the lead acetate paper. Samples were compared to

standard papers treated in the same manner. Results are reported as a minimum and maximum concentration of sulfide in the samples, based on a visual comparison of the papers.

- COD (Chemical Oxygen Demand): Standard Methods - 508

- Percent Voids

  The void space between gravel was measured by filling a 250 ml graduated cylinder with gravel. Water was added to the gravel-filled graduated cylinder and brought to the 250 ml mark. The water was then poured off into a second graduated cylinder and the volume recorded. Percent voids were then calculated as the volume of water measured, divided by 250 ml x 100.

Leachate Analyses

All analytical procedures used in evaluating the leachate were standard methods routinely used in environmental analyses. The exact methods and all deviations from the published procedures can be seen below. Well-mixed subsamples taken from the sample cubitainers were used for leachate analyses.

- ph: Standard Methods - 424

- ORP (Oxidation Reduction Potential): ASTM - D1498-76

- Conductivity: Standard Methods - 205

- Total Solids: Standard Methods- 208D

  Samples were dried in 103-105°C oven for a minimum of two days. It was determined that this length of time was required to bring the samples to constant weight.

- Total Volatile Solids: Standard Methods - 208G

- COD (Chemical Oxygen Demand): Standard Methods - 508

- TOC (Total Organic Carbon): Standard Methods - 415.1

  Analyses were performed on a Beckman Tocamaster Carbon Analyzer. Acidified samples were purged with oxygen to eliminate inorganic carbon.

- Total Phosphate: Standard Methods - 425F

  All glassware was acid washed with 1:1 HCl to eliminate residual phosphate.

- Metals (Cd, Cr, Cu, Fe, Ni, Pb, Zn): Standard Methods - 304A, 307A, 308A, 310B, 311A, 316A, 323A

  A Perkin-Elmer Model 343 Atomic Absorption Spectrophotometer was used for all metals analyses. One hundred milliliters of leachate were concentrated to 25 milliliters through a HNO_3/HCl digestion as described in SW-846, Test Methods for Evaluating Solid Waste, Method 3010.

SECTION 5

DATA AND DISCUSSION

In addition to the following data, a complete set of colored slides and photographs and black and white photographs were compiled to document in pictorial fashion the conditions observed. In general the conditions were not too different between the codisposal cells and the refuse-only cells. Data are presented on the various tasks described in the objectives. All analyses were not performed on every cell. As described earlier, each analysis was performed on a limited number of lysimeters. (See Table 2)

MICROBIOLOGY OF REFUSE

In order to determine the ability of the pathogenic indicators to survive and to determine which types of organisms were actively stabilizing the waste materials within the cells, the refuse in the municipal refuse only and the industrial refuse/municipal refuse codisposal cells were examined for the presence of aerobic and anaerobic bacteria, fungi, total coliforms, fecal coliforms and fecal streptococci. Since there was no clear layering in the industrial waste cells (with the exception of cells 14 and 17, where the waste was still found in large clumps) grab samples from all cells were taken at random sample depths rather than in the specific industrial or municipal refuse layer. No samples were taken from the clumps of industrial waste in cells 14 and 17. (See Section 4 and Appendix C for exact sample depths).

Early in the refuse removal, a large number of intact disposable diapers containing fecal matter were found. In order to evaluate the impact of the diapers on the overall microbiology of the refuse, diapers were sampled in place of the refuse from some of the cells. Table 3 in the Procedures Section indicates the type of samples taken at each sample level in each test lysimeter. Originally, the project called for analysis of cells 3,7,9,10,12, 13,14,17, and 18; three municipal refuse only and six codisposal cells. In order to establish a larger data base for comparing municipal-only cells with codisposal cells, three additional municipal-only cells, 1,16, and 19, were also analyzed. All of the microbiological data are presented here in terms of how the organisms were found in the test lysimeters. That is, the data are based on the wet weight of the samples. For comparison with other data, the organism enumerations are presented in Appendix A on a dry weight basis. Total moisture contents of the samples (Appendix D) did not vary that much from sample to sample, therefore, the relative results remained essentially the same for all enumerations whether considered on a wet weight basis or dry weight basis.

Microbe Indicator Groups in the Industrial Refuse/Municipal Refuse Cells

The total coliform population in the three sample levels varied from cell to cell. (Table 5) Populations decreased from top to bottom in two cells, 9 and 12, and increased in cell 10. Cells 14 and 17 increased from Sample A to B and then decreased from Sample B to C. Cell 13 decreased from Sample A to B and increased from B to C. Although there is no clear trend in total coliform populations, these data clearly indicate the presence of the coliforms throughout the industrial refuse codisposal cells after a ten-year period. The highest levels of total coliforms were recorded in the three diaper samples analyzed for the codisposal cells.

TABLE 5. INDUSTRIAL REFUSE CODISPOSAL CELLS: TOTAL COLIFORMS
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
9	$4.90x10^4$	$3.50x10^4$	$5.40x10^3$
10	$< 2.00x10^1$	$3.30x10^2$	$1.80x10^3$
12	$7.00x10^2$	$2.70x10^2$	2.00810^1
13	$7.90x10^6$*	$2.20x10^2$	$2.80x10^3$
14	$2.60x10^2$	$9.20x10^4$	$1.70x10^3$
17	$1.00x10^3$	$9.20x10^7$*	$3.50x10^5$*

* Diaper

Table 6 shows the numbers of fecal coliforms found at each sample level. Cells 14 and 17 increased slightly in fecal coliform populations from top to bottom of the cells. Test cells 9 and 13 decreased in the number of colonies counted from top to bottom. Levels of fecal coliforms stayed essentially the same at all sample levels in cells 10 and 12. Again there are no clear trends in these data. Although the relative numbers of fecal coliforms found were low, they clearly confirm the presence of fecal coliforms in the cells. The highest levels of fecal coliforms were not found in the diaper samples.

The fecal streptococci (Table 7) varied very little overall from the top to the bottom of the test cells. Only test cell 9 showed a clear decrease from top to bottom of the cell. Test cells nos. 12 and 13 decreased from Sample A to B and increased from Sample B to C. Cell 10 increased from Sample A to Sample B and decreased from B to C. Test cell 14 increased from Sample A to B and maintained those levels of fecal streptococci at the bottom. Cell 17 decreased from Sample A to B and stayed the same at Level C. Again, the highest levels of fecal streptococci were not found in the diaper samples.

TABLE 6. INDUSTRIAL REFUSE CODISPOSAL CELLS: FECAL COLIFORMS
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
9	5.40×10^{3}	7.00×10^{1}	$< 2.00\times10^{1}$
10	$< 2.00\times10^{1}$	$< 2.00\times10^{1}$	2.00×10^{2}
12	$< 2.00\times10^{1}$	$< 2.00\times10^{1}$	$< 2.00\times10^{1}$
13	8.00×10^{1}*	$< 2.00\times10^{1}$	$< 2.00\times10^{1}$
14	8.00×10^{2}	2.20×10^{4}	3.30×10^{2}
17	8.00×10^{2}	$< 2.00\times10^{2}$*	3.30×10^{3}*

* Diaper

TABLE 7. INDUSTRIAL REFUSE CODISPOSAL CELLS: FECAL STREPTOCOCCI
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
9	3.50×10^{4}	1.40×10^{3}	4.90×10^{2}
10	5.00×10^{1}	5.00×10^{2}	2.00×10^{2}
12	3.30×10^{3}	2.30×10^{3}	1.70×10^{5}
13	1.70×10^{3}*	2.00×10^{2}	2.40×10^{3}
14	4.00×10^{2}	7.90×10^{3}	7.90×10^{3}
17	2.40×10^{5}	4.90×10^{3}*	4.90×10^{3}*

* Diaper

Clostridium perfringens (Table 8), another indicator organism from fecal matter, was found in relatively large numbers from the top to the bottom of the test cells. Test cell 10 clearly increased from top to bottom, while cell 13 decreased from top to bottom. The counts from test cells 9 and 17 stayed essentially the same from top to bottom. Test cell 12 decreased from Sample A to B, then increased from Sample B to C. Test cell 14 increased from Sample A to B and returned to Sample A levels in Sample C. The diaper samples showed the highest levels of Clostridium perfringens, however, it should be noted that the non-diaper samples from those cells (13 and 17) also showed higher levels than most of the other samples.

TABLE 8. INDUSTRIAL REFUSE CODISPOSAL CELLS: CLOSTRIDIUM PERFRINGENS STORMY FERMENTATION
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
9	2.20×10^{6}	7.00×10^{6}	9.20×10^{6}
10	3.50×10^{5}	2.40×10^{6}	1.10×10^{7}
12	7.90×10^{6}	1.30×10^{5}	1.80×10^{7}
13	1.30×10^{7}*	9.20×10^{6}	7.90×10^{5}
14	3.30×10^{5}	5.40×10^{6}	3.10×10^{5}
17	1.10×10^{7}	2.20×10^{7}*	5.40×10^{7}*

* Diaper

Another evaluation of Clostridium perfringens levels was obtained by a tryptone sulfite cycloserine plate count. (Table 9) The results of these plate counts were lower than the results of the Clostridium MPN tests. There were no clear trends between nor within the results of the two Clostridium perfringens enumerations. Test cell 10 increased in the number of organisms from top to bottom. Counts from test cell 17 decreased from top to bottom. Test cells 9 and 14 increased from Sample A to B and decreased from Sample B to C. Cells 12 and 13 decreased from Sample A to B and increased from Sample B to C. Although these numbers differ from the MPN Clostridium perfringens numbers, they both confirm the presence of Clostridium perfringens in relatively high numbers throughout all codisposal cells.

TABLE 9. INDUSTRIAL REFUSE CODISPOSAL CELLS: *CLOSTRIDIUM PERFRINGENS*
TRYPTONE SULFITE CYCLOSERINE AGAR
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
9	$1.70\text{x}10^{5}$	$3.10\text{x}10^{7}$	$9.80\text{x}10^{6}$
10	$1.40\text{x}10^{5}$	$1.80\text{x}10^{6}$	$1.20\text{x}10^{7}$
12	$1.20\text{x}10^{6}$	$4.00\text{x}10^{4}$	$3.20\text{x}10^{6}$
13	$3.00\text{x}10^{5}$*	$2.40\text{x}10^{5}$	$1.30\text{x}10^{6}$
14	$3.70\text{x}10^{5}$	$9.50\text{x}10^{5}$	$3.90\text{x}10^{5}$
17	$9.00\text{x}10^{4}$	$2.00\text{x}10^{4}$*	$< 1.00\text{x}10^{4}$*

* Diaper

TABLE 10. INDUSTRIAL REFUSE CODISPOSAL CELLS: TOTAL PLATE COUNT (AEROBIC)
STANDARD METHODS AGAR
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
9	$2.12\text{x}10^{10}$	$4.60\text{x}10^{8}$	$1.60\text{x}10^{10}$
10	$2.80\text{x}10^{6}$	$3.70\text{x}10^{7}$	$2.00\text{x}10^{10}$
12	$1.40\text{x}10^{10}$	$1.10\text{x}10^{10}$	$5.50\text{x}10^{9}$
13	$1.30\text{x}10^{9}$*	$1.10\text{x}10^{9}$	$1.10\text{x}10^{7}$
14	$1.70\text{x}10^{10}$	$1.70\text{x}10^{10}$	$9.50\text{x}10^{9}$
17	$3.70\text{x}10^{10}$	$5.30\text{x}10^{10}$*	$5.20\text{x}10^{9}$*

*Diaper

Total plate counts (Table 10) made from the industrial refuse/municipal refuse test cells indicated large numbers of aerobic and facultative anaerobic organisms throughout each cell. Data from each sample level varied from cell to cell. Counts in test cell 10 increased from top to bottom. Test cell 9 decreased by two orders of magnitude from Sample A to Sample B and then returned to original levels at Sample C. Test cells 12, 14, and 17 stayed at essentially the same levels from Sample A to B and decreased by one to two orders of magnitude from Sample B to C. Test cell 13 decreased from Sample A to B and stayed the same from B to C. Diaper samples showed similar count to the non-diaper samples.

Total plate counts for anaerobes (Table 11) showed relatively high levels of anaerobic and facultative anaerobic organisms throughout each codisposal lysimeter. There were no clear trends from sample level to sample level. Cells 10 and 17 increased from top to bottom. Cell 13 decreased from top to bottom. Cells 12 and 14 increased from Sample A to B and decreased from Sample B to C. Cell 9 decreased from Sample A to B and increased from Sample B to C. The highest level was found in Sample B from cell 14.

TABLE 11. INDUSTRIAL REFUSE CODISPODAL CELLS: TOTAL PLATE COUNT (ANAEROBIC)
STANDARD METHODS AGAR
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
9	1.10×10^8	2.90×10^7	3.40×10^8
10	5.10×10^5	4.10×10^7	7.15×10^7
12	7.10×10^8	8.10×10^9	2.56×10^7
13	6.00×10^9*	9.30×10^8	1.00×10^7
14	9.80×10^9	1.00×10^{10}	5.50×10^9
17	2.60×10^8	2.80×10^8*	6.80×10^9*

*Diaper

Gram negative rod organisms (Table 12) decreased from the top to the bottom in cells 9 and 14. Cell 10 increased by six orders of magnitude from Sample A to B and then decreased by three orders of magnitude from Sample B to C. Cells 13 and 17 stayed the same from Sample A to B and decreased from Sample B to C. Cell 12 decreased from Sample A to B and stayed at essentially the same levels from Sample B to Sample C.

TABLE 12. INDUSTRIAL REFUSE CODISPOSAL CELLS: GRAM NEGATIVE RODS MACCONKEY AGAR (Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
9	$4.10\text{x}10^{9}$	$2.70\text{x}10^{8}$	$1.70\text{x}10^{7}$
10	$< 1.00\text{X}10^{4}$	$2.20\text{X}10^{10}$	$3.90\text{x}10^{7}$
12	$1.20\text{x}10^{10}$	$1.50\text{x}10^{9}$	$7.50\text{x}10^{9}$
13	$4.60\text{x}10^{7}$*	$3.80\text{x}10^{7}$	$2.30\text{x}10^{5}$
14	$1.10\text{x}10^{10}$	$9.10\text{x}10^{9}$	$5.30\text{x}10^{5}$
17	$1.70\text{x}10^{10}$	$1.20\text{x}10^{10}$*	$6.50\text{x}10^{8}$*

* Diaper

TABLE 13. INDUSTRIAL REFUSE CODISPOSAL CELLS: FUNGI ROSE BENGAL AGAR (Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
9	$5.30\text{x}10^{7}$	$5.40\text{x}10^{7}$	$2.40\text{x}10^{7}$
10	$4.50\text{X}10^{6}$	$3.50\text{X}10^{6}$	$1.40\text{x}10^{7}$
12	$2.10\text{x}10^{8}$	$3.20\text{x}10^{6}$	$3.50\text{x}10^{6}$
13	$5.50\text{x}10^{6}$*	$8.80\text{x}10^{6}$	$3.20\text{x}10^{5}$
14	$1.10\text{x}10^{5}$	$5.50\text{x}10^{6}$	$1.10\text{x}10^{7}$
17	$4.00\text{x}10^{4}$	$2.10\text{x}10^{5}$*	$1.00\text{x}10^{4}$*

* Diaper

Fungi counts for each level of the codisposal cells can be seen in Table 13. Test cell 14 increased from top to bottom of the cell. Test cell 17 increased from Sample A to B and decreased from Sample B to C. Test cell 12 decreased from Sample A to B and increased from Sample B to C. Counts from cell 9 stayed essentially the same from top to bottom. Cells 10 and 13 stayed the same from Sample A to B, then counts in cell 10 increased at Sample C while counts decreased at Sample C in cell 13. The fungi counts from the three diaper samples were lower than most of the other samples.

In the codisposal cells there were no clear trends from sample level to sample level within a given cell. There are relatively high numbers of organisms existing at all levels within the lysimeters. No cell differed significantly in any counts from the other industrial codisposal cells.

Microbe Indicator Groups in the Refuse-Only Cells

In the municipal refuse only cells, the total coliform levels (Table 14) varied from level to level in each cell. Again, this data indicates no clear trends. Cells 1 and 18 increased from top to bottom. Cells 7 and 19 decreased from top to bottom. Cells 3 and 16 decreased from Sample A to B and increased from Sample B to C. Two of the samples, Sample 18B (a diaper sample) and 18C (a non-diaper sample), had total coliform counts that were significantly higher than the other samples.

TABLE 14. MUNICIPAL REFUSE CELLS: TOTAL COLIFORMS
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
1	$2.20\text{x}10^5$	$5.40\text{x}10^5$	$1.70\text{x}10^6$
3	$3.50\text{X}10^6$	$3.50\text{x}10^4$*	$1.70\text{x}10^5$
7	$1.30\text{x}10^5$	$1.90\text{x}10^3$	$1.30\text{x}10^2$
16	$1.60\text{x}10^5$	$2.60\text{x}10^3$*	$5.40\text{x}10^4$
18	$9.20\text{x}10^5$	$2.40\text{x}10^{11}$*	$2.40\text{x}10^{11}$
19	NA	$5.40\text{x}10^4$*	$2.20\text{x}10^4$

NA: Not Analyzed * Diaper

The fecal coliforms (Table 15) were generally present in fairly low levels throughout the cells. Sample 19 increased from Sample B, a diaper sample, to Sample C, a non-diaper sample. Cells 1 and 16 had essentially the same low levels of fecal coliforms from the top to the bottom of the cells. Cells 3 and 7 decreased from Sample A to B and remained at the same low levels in Sample C. Cell 18 again had levels higher then the other refuse-only cells. Fecal coliforms increased from top to bottom in cell 18. The highest count recorded, $5.40x10^{7}$, was found in Sample C of cell 18.

TABLE 15. MUNICIPAL REFUSE CELLS: FECAL COLIFORMS
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
1	$4.00x10^{1}$	$< 2.00x10^{1}$	$< 2.00x10^{1}$
3	$2.30X10^{5}$	$< 2.00X10^{1}$*	$< 2.00x10^{1}$
7	$2.40x10^{4}$	$< 2.00x10^{1}$	$< 2.00x10^{1}$
16	$< 2.00x10^{1}$	$< 2.00x10^{1}$*	$5.00x10^{1}$
18	$5.40x10^{5}$	$9.20x10^{5}$*	$5.40x10^{7}$
19	NA *	$< 2.00x10^{1}$*	$7.90x10^{2}$

NA: Not Analyzed * Diaper

Fecal *streptococci* (Table 16) were more varied from cell to cell than the other indicator organisms. However, as in the other tests,there were no clear trends in the data. Cells 1 and 3 increased in fecal *streptococci* counts from top to bottom. Cell 10 decreased from top to bottom. Cells 18 and 7 increased from Sample A to B and decreased from Sample B to C. Cell 16 decreased from Sample A to B and increased from Sample B to C. Again, cell 18 had higher levels than the other cells, and the diaper sample from 18B had the highest fecal *streptococci* levels of all samples.

Clostridium perfringens numbers were found in the same varying levels as the other indicator organisms. (Table 17) Cells 16 and 19 increased from top to bottom. Cells 3, 7 and 18 increased from Samples A to B and then decreased from Sample B to C. The highest *Clostridium perfringens* level was found in a non-diaper sample from cell 19 at sample level C where levels of $9.20x10^{8}$ colonies/100 grams were recorded.

TABLE 16. MUNICIPAL REFUSE CELLS: FECAL STREPTOCOCCI (Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
1	2.40×10^{6}	2.40×10^{6}	3.50×10^{7}
3	4.90×10^{3}	1.30×10^{4}*	1.10×10^{4}
7	6.70×10^{2}	1.60×10^{6}	1.30×10^{3}
16	2.20×10^{3}	$< 2.00\times10^{1}$*	3.50×10^{4}
18	9.20×10^{5}	1.30×10^{8}*	2.40×10^{7}
19	NA	7.90×10^{6}*	7.90×10^{3}

NA: Not Analyzed * Diaper

TABLE 17. MUNICIPAL REFUSE CELLS: *CLOSTRIDIUM PERFRINGENS* STORMY FERMENTATION (Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
1	NA	NA	NA
3	5.40×10^{6}	3.50×10^{7}*	7.00×10^{5}
7	7.90×10^{5}	2.80×10^{6}	2.40×10^{6}
16	2.70×10^{5}	3.50×10^{5}*	9.20×10^{5}
18	9.20×10^{5}	7.90×10^{7}*	2.50×10^{6}
19	NA	9.20×10^{6}*	9.20×10^{8}

NA: Not Analyzed * Diaper

The tryptone sulfite cycloserine plate counts for *Clostridium perfringens* were generally lower than the MPN counts for *Clostridium perfringens* in the municipal refuse only cells (Table 18). Again, counts varied from sample level to sample level within a given cell and no clear trends were observed. Cells 3 and 19 counts increased from the middle of the cell to the bottom of the cell. Cells 16 and 18 decreased from Sample A to Sample B and increased from Sample B to C. Cell 7 increased from Sample A to B, then decreased from Sample B to C. Although these counts are slightly lower than the MPN results, they still confirm high levels of *Clostridium perfringens* at all levels in each test cell.

TABLE 18. MUNICIPAL REFUSE CELLS: *CLOSTRIDIUM PERFRINGENS*
TRYPTONE SULFITE CYCLOSERINE
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
1	NA	NA	NA
3	7.00×10^4	3.70×10^5*	3.00×10^4
7	6.10×10^6	7.50×10^6	2.00×10^5
16	4.00×10^5	3.90×10^5*	1.20×10^5
18	3.65×10^6	1.00×10^4*	5.10×10^5
19	NA	1.10×10^5*	5.00×10^6

NA: Not Analyzed *Diaper

The total plate counts for aerobic organisms (Table 19) indicated high levels of aerobes and/or facultative anaerobes throughout each lysimeter. Again the data showed no clear trends, varying from sample level to sample level in each of the lysimeters. Cells 16 and 19 had lower counts at each recorded level than the other cells. Cells 7, 16 and 18 all decreased from Sample A to B and increased from Sample B to C. Cell 3 increased in total counts from A to B and stayed the same from B to C. Cell 19 stayed essentially the same at the two levels analyzed. The highest levels were found in a nondiaper sample from cell 7.

TABLE 19. MUNICIPAL REFUSE CELLS: TOTAL PLATE COUNT (AEROBIC) STANDARD METHODS AGAR (Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
1	NA	NA	NA
3	2.70×10^{9}	1.60×10^{10}*	1.70×10^{10}
7	7.40×10^{10}	4.10×10^{8}	1.20×10^{12}
16	5.10×10^{8}	1.02×10^{7}*	4.80×10^{8}
18	2.02×10^{10}	3.55×10^{9}*	2.40×10^{10}
19	NA	1.20×10^{7}*	1.40×10^{7}

NA: Not Analyzed *Diaper

The total plate counts for anaerobic organisms can be seen in Table 20. These counts were similar in magnitude to the aerobic plate counts. These data indicate large numbers of anaerobes and/or facultative anaerobes throughout each test cell. Cells 3, 18 and 19 stayed essentially the same from top to bottom. Cell 16 increased from Sample A to B and decreased from Sample B to C. Cell 7 decreased from Sample A to B and increased from Sample B to C. The highest counts were recorded from the non-diaper sample at 3C.

The levels of gram negative rods found in the refuse-only cells can be seen in Table 21. There was more variation between the cells in terms of relative levels of the gram negative counts than in any of the other enumerations. Each cell had different levels of gram negative organisms, such that they can be clearly ordered in terms of descending magnitude. Cell 18, whose counts increased from the top to the middle and bottom samples, had the highest counts of all cells. The highest count recorded (1.13×10^{12} colonies /100 grams wet) was from a diaper at sample level B in cell 18. Cell 1, with the next highest counts, increased from top to bottom. Cell 7 had high counts in Samples A and B, which decreased to the lowest recorded count at Level C. Cell 3 had the next highest counts, which decreased from top to bottom. Cell 16, next in relative magnitude, decreased from Sample A to B and increased from Sample B to C. Cell 19, with the lowest relative counts, increased slightly from the middle to the bottom of the cell.

TABLE 20. MUNICIPAL REFUSE CELLS: TOTAL PLATE COUNT (ANAEROBIC) STANDARD METHODS AGAR (Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
1	NA	NA	NA
3	3.00×10^{10}	4.80×10^{10}*	1.70×10^{11}
7	7.20×10^{10}	2.50×10^{8}	2.30×10^{9}
16	1.90×10^{8}	1.13×10^{9}*	1.09×10^{8}
18	3.45×10^{9}	4.35×10^{9}*	2.45×10^{9}
19	NA	1.20×10^{7}*	1.20×10^{7}

NA: Not Analyzed * Diaper

TABLE 21. MUNICIPAL REFUSE CELLS: GRAM NEGATIVE RODS MACCONKEY AGAR (Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
1	2.09×10^{10}	2.89×10^{10}	7.80×10^{10}
3	3.30×10^{8}	3.40×10^{7}*	3.30×10^{7}
7	1.90×10^{10}	6.20×10^{8}	3.00×10^{4}
16	6.85×10^{6}	1.83×10^{5}*	5.05×10^{7}
18	5.68×10^{10}	1.13×10^{12}*	7.10×10^{11}
19	NA	2.40×10^{5}*	6.00×10^{5}

NA: Not Analyzed * Diaper

TABLE 22. MUNICIPAL REFUSE CELLS: FUNGI
ROSE BENGAL AGAR
(Colonies/100 grams wet weight)

Test Cell	Sample A	Sample B	Sample C
1	NA	NA	NA
3	3.50×10^5	3.00×10^4*	8.50×10^4
7	3.60×10^7	3.90×10^5	1.30×10^5
16	6.50×10^4	2.25×10^4*	2.30×10^5
18	2.53×10^5	8.05×10^7*	5.00×10^7
19	NA	$< 1.00 \times 10^4$*	2.00×10^6

NA: Not Analyzed * Diaper

The fungi levels found in the refuse-only cells can be seen in Table 22. These data were similar in their relative magnitude and showed the same variation from sample level to sample level seen in all of the other data. The data clearly indicate the presence of the fungi throughout each test lysimeter. Cell 7 decreased from top to bottom. Cell 19 increased from the middle sample to the bottom sample. Cells 3 and 16 decreased from Sample A to B and increased from Sample B to C. Cell 18 increased from Sample B to C and decreased from Sample B to C. The highest counts were recorded in the diaper sample at 18B.

The data from the refuse-only cells showed no clear trends from sample level to sample level for any of the analyses. Cell 18 routinely had higher counts at all levels than any of the other refuse-only cells. Several conditions may contribute to these higher counts. First, this cell was located inside of the high bay, which would result in less variation. Cells 16 and 19 were also inside lysimeters, however, they did not show similar high results. Cell 18 was also packed six months after the other cells, but again cell 19 was also loaded at this later time and did not show higher results. The variation in the cell 18 results is probably due more to sample material and location within the cell, rather than any identifiable external factors that may have affected the cells. The data from the municipal-only cells clearly indicates high levels of all organisms, with the exception of fecal coliforms, throughout all cells. Although fecal coliforms were not present at the same levels as the other organisms, they were still present, indicating survival even after ten years.

MICROBE INDICATOR GROUPS: INDUSTRIAL CODISPOSAL CELLS VS. REFUSE ONLY CELLS

Figures 5 to 13 compare the results obtained from the codisposal cells with the results from the refuse-only cells. These graphs clearly indicate there were no major differences between codisposal and refuse-only cells in the numbers of organisms typically expected to be found in refuse. Both types of cells showed similar variation from sample level to sample level within a given test cell. No cell showed any clear trends from sample level to sample level for any of the organisms.

Quantification of the microbes commonly used as indicators of fecal population identified at the termination of the ten-year overall project can be compared in a general sense with data generated from measurements made at the start of the study and measurements made two years into the study[9]. These data are presented in Table 23.

TABLE 23. INDICATOR ORGANISM LEVELS OVER 10 YEARS
(colonies/100 grams wet weight)

	Initial Count	2-Year Count	10-Year Codisposal	10-Year Refuse Only
Total Coliforms	6.2×10^{10}	5.6×10^{6}	1.8×10^{4}	1.4×10^{5}
Fecal Coliforms	2.6×10^{9}	5.6×10^{5}	7.5×10^{1}	$< 2.0\times10^{1}$
Fecal Streptococci	1.4×10^{10}	1.6×10^{6}	2.4×10^{3}	2.4×10^{4}

The initial counts were made on the eleven separate categories in the Fall of 1974 and with a different truckload on the eleven categories in the Spring of 1975. Two-year counts were made on the municipal refuse in cell 15, and the ten-year counts are the median values of the data discussed previously.

The total coliforms decreased by four orders of magnitude from the start to two years. After ten years, the industrial codisposal cells decreased by two orders of magnitude and the refuse-only cells decreased by one order of magnitude over the two-year measurement. No cells recovered to the initial measurement.

The fecal coliforms counts showed the largest change from start to finish of the project. This is as would be expected, since the fecal coliforms are the most sensitive of the indicator organisms. Counts decreased by four orders of magnitude from initial measurements to two years. After ten years, both types of cells decreased by another four orders of magnitude.

Fecal streptococci populations decreased by four orders of magnitude from start to two years. After ten years, the industrial codisposal cells decreased by an additional three orders of magnitude, while the refuse-only

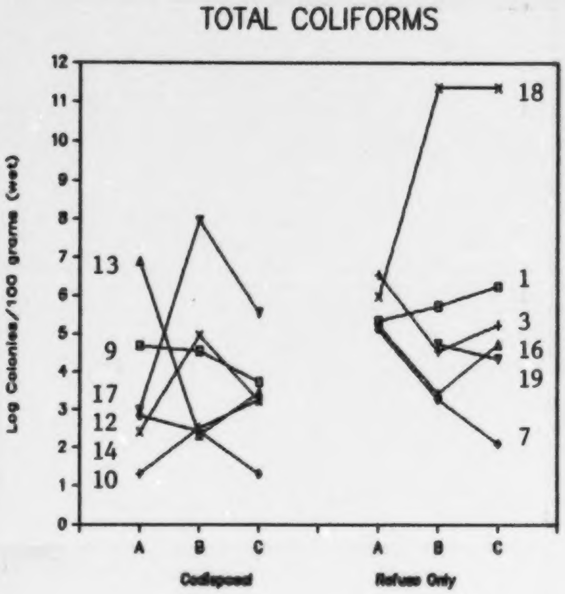


Figure 5

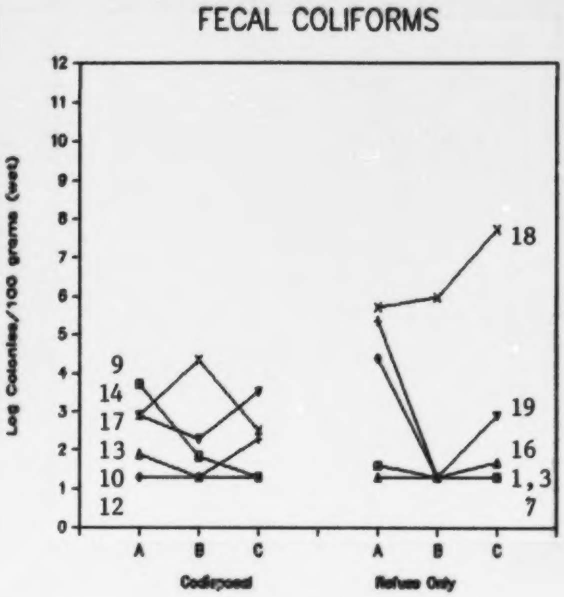


Figure 6

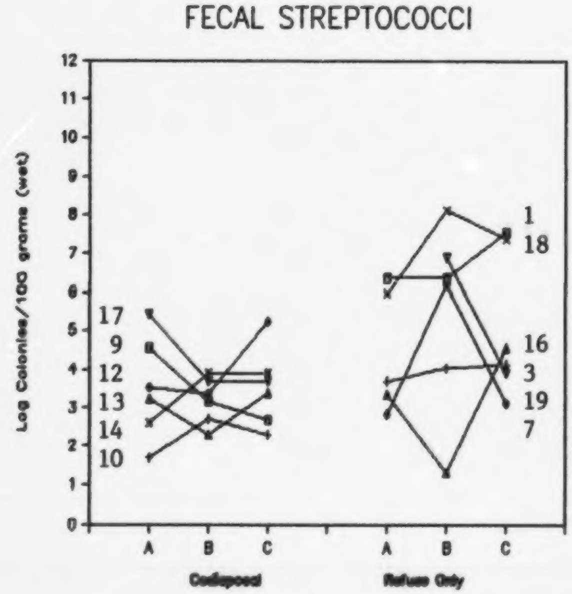


Figure 7

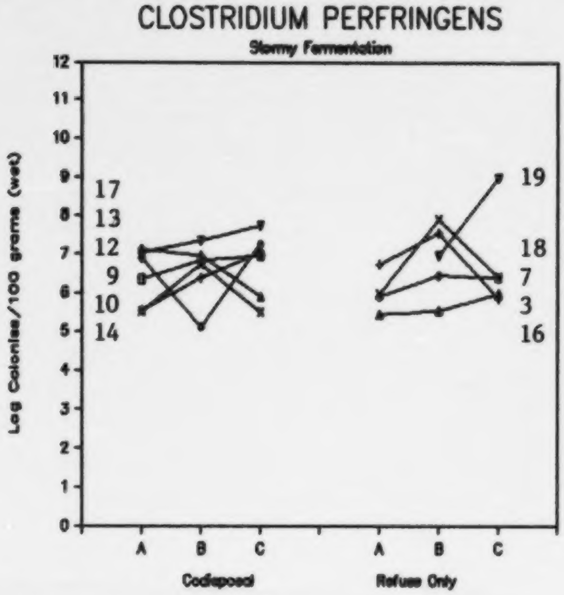


Figure 8

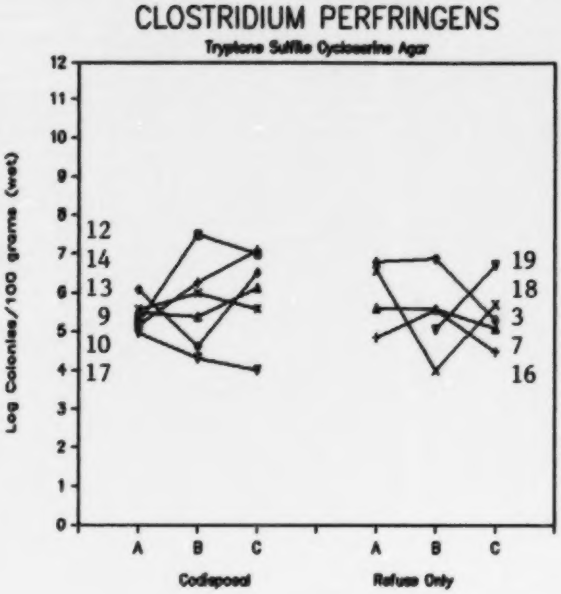


Figure 9

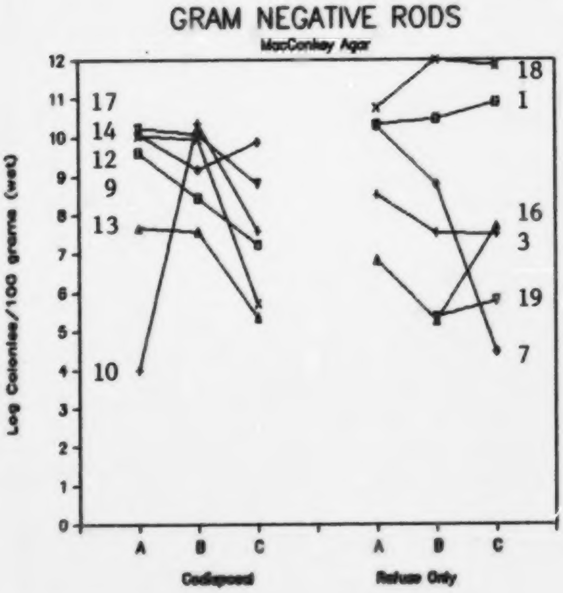


Figure 10

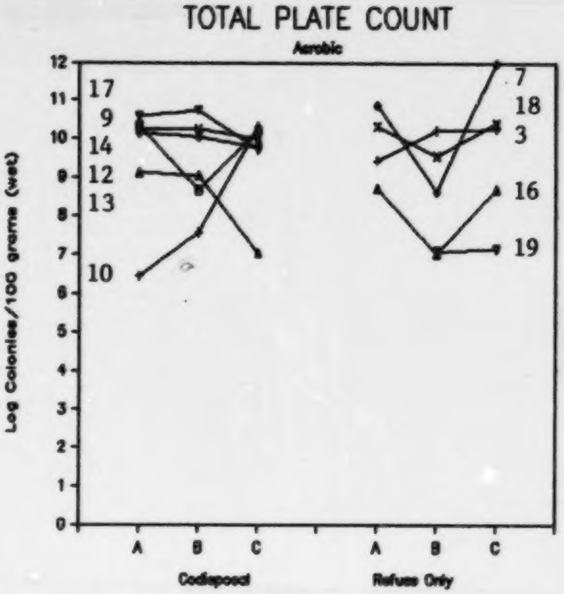


Figure 11

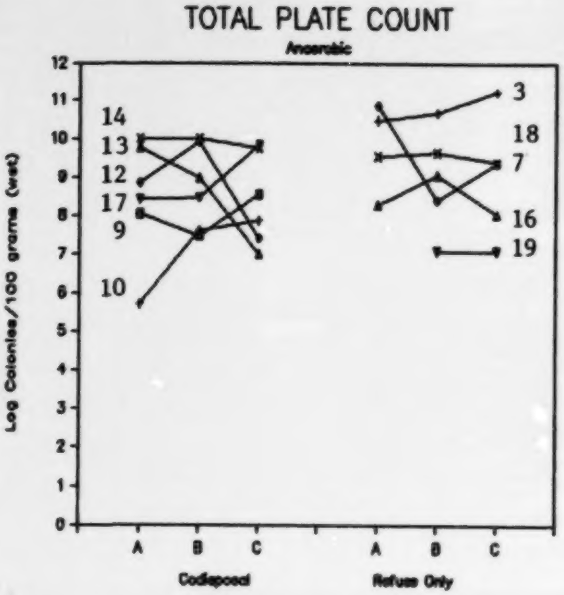


Figure 12

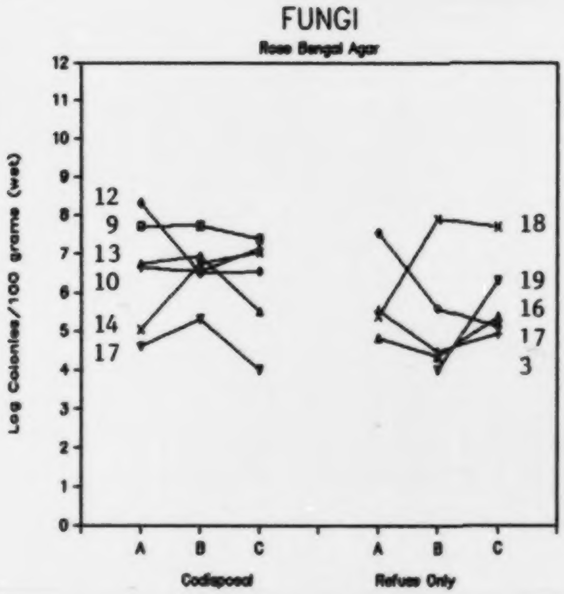


Figure 13

cells decreased by two orders of magnitude from the two-year measurement. Neither recovered to the initial populations.

The indication is that the lysimeter environment changed within the first two years. This change caused a decline in the fecal indicator organism population. Through the two- to ten-year period, these organisms were able to maintain their populations, but not at the initial levels. This was not unexpected. Decomposition of fecal matter would be expected to proceed rather rapidly, leaving less substrate for these organisms and perhaps cause the loss of some required trace nutrients which would limit population levels.

Identification, Quantification and Comparison of Microorganisms

Quantification

It was not possible to isolate all species which might be present in the refuse. An attempt was made to identify all of the anaerobes, gram negative rods, and fungi. However, some organisms died prior to identification and sometimes the fungal spores necessary for identification did not develop. Therefore, some species may have been present that were not identified. Figure 14 compares the number of different species of microorganisms in each refuse-only test cell with the industrial refuse codisposal cells at each level. The mean numbers at each level are not significantly different. Level A had a total of 39 different species in the refuse-only cells and 22 different species in the codisposal cells. The mean number of different species for all similar cells was ten and four for refuse-only and codisposal cells, respectively. Level B had similar numbers in both types of test cells. Refuse-only cells had a total number of 26 different species with a mean of six, and the codisposal cells had a total number of 33 different species with a mean of six. At Level C, 17 different species were identified in the refuseonly cells, while 28 different species were identified in the industrial codisposal cells. The means were four and five species for refuse-only and industrial codisposal cells, respectively.

In comparing the numbers of different species found, it should be noted that only four refuse-only cells and six codisposal cells were used in this quantification. It is not particularly surprising, nor can any conclusions be drawn from the fact that there were more different species in the codisposal cells at Levels B and C. It is interesting that there were more different species in the Level A samples of the four refuse-only cells than in the six codisposal cells. However, there were insufficient data to determine the reason for this difference.

Tables 24, 25, 26 and 27 compare the species identified in the refuse-only cells and the industrial codisposal cells at each level. In each of these tables, the first grouping of microorganisms is all gram positive, strictly anaerobic species of the genus Clostridium. The second grouping of microorganisms is the fungi, and the third grouping is all gram negative rods.

At Level A (Table 24), there is a greater number of species of microbes

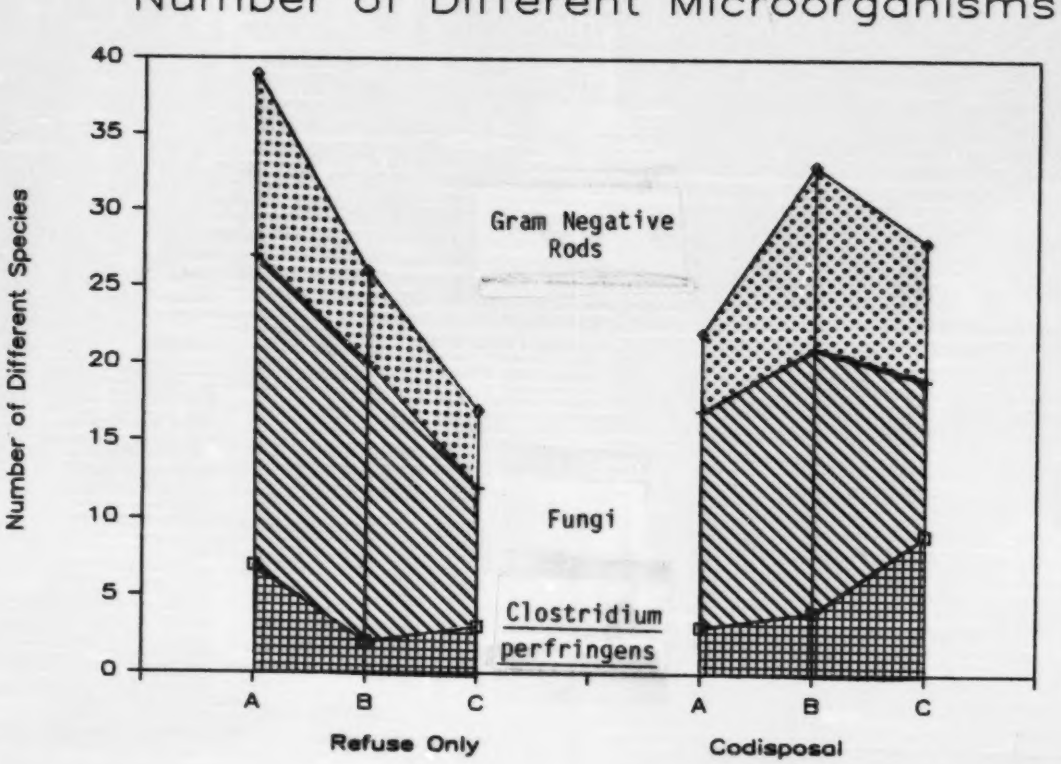


Figure 14

in the refuse-only cells than in the codisposal cells (39 to 22, respectively). Similar species to both types include Clostridium perfringens, genus Penicillium, genus Aspergillus, yeast, genus Cladosporium, genus Trichophyton, Enterobacter cloacae, Vibrio fluvialis, Klebsiella pneumoniae, and genus Pseudomonas.

At Level B (Table 25), there is not a great difference in the number of different species (26 to 31 for refuse-only to codisposal cells, respectively). The species similar to both types were Clostridium perfringens, genus Aspergillus, genus Cladosporium, genus Sepedonium, Yeast-Rhodotorula, genus Paecilomyces, Vibrio fluvialis, genus Alternaria, genus Trichophyton, Entero-

bacter agglomerans, and genus *Pseudomonas*. These can live and grow under a wider range of conditions and are therefore more adaptable and tolerant to the changes in pH and temperature within the lysimeters.

At Level C (Table 26), the industrial codisposal cells had a total number of 28 species identified, while the refuse-only cells had a total number of 17 different species. One of the main differences at this level was with the genus *Clostridium*. Only three *Clostridium* species were identified in the refuse-only cells, while nine *Clostridium* species were identified in the industrial codisposal cells. Similar species to both types of cells include *Clostridium perfringens*, genus *Cladosporium*, genus *Penicillium* and yeast.

In the diaper samples (Table 27), the refuse-only cells identified 19 species of microbes, while the codisposal cells had 15 different species. Seven species were common to both types of cells.

TABLE 24. SPECIES FOUND IN REFUSE-ONLY vs. INDUSTRIAL CODISPOSAL CELLS
Level A

REFUSE-ONLY CELLS	INDUSTRIAL CODISPOSAL CELLS
Clostridium bifermentans	
Clostridium botulinum	*Clostridium botulinum* (Group II)
Clostridium difficile	
Clostridium hastiforme	
Clostridium histolyticum	
Clostridium novyi	
Clostridium perfringens	*Clostridium perfringens*
	Clostridium sordellii
Absidia sp.	*Absidia* sp.
Aspergillus sp.	*Aspergillus* sp.
	Aspergillus flavus
Aspergillus fumigatus	*Aspergillus fumigatus*
	Aspergillus nidulans
Aspergillus niger	
Cephalosporium sp.	*Cephalosporium sp.*
Chaetomium sp.	
Cladosporium sp.	*Cladosporium* sp.
Epidermophyton floccosum	
Fonsecaea compactum	
Geotrichum sp.	
Madurella sp.	
Microsporium apiospermum	
	Monosporium apiospermum
	Nigrospora sp.
Paecilomyces sp.	*Paecilomyces* sp.
Penicillium sp.	*Penicillium* sp.
	Rhizopus sp.
Rhodotorula sp.	
Scopulariopsis sp.	
	Sepedonium sp.
Syncephalastrum sp.	
Trichoderm sp.	
Trichophyton sp.	*Trichophyton* sp.
Yeast	Yeast

(continued)

TABLE 24. SPECIES FOUND IN REFUSE-ONLY vs. INDUSTRIAL CODISPOSAL CELLS Level A (cont.)

REFUSE-ONLY CELLS	INDUSTRIAL CODISPOSAL CELLS
Acinetobacter sp.	
Acinetobacter calcoaceticus var. anitratus	
Acinetobacter calcoaceticus var. lwoffi	
Alcaligenes sp.	
Citrobacter freundii	
Enterobacter cloacae	*Enterobacter cloacae*
Hafnia alvei	
Klebsiella pneumoniae	*Klebsiella pneumoniae*
	Klebsiella oxytoca
Pseudomonas sp.	*Pseudomonas* sp.
Serratia fonticola	
Tatemella ptyseos	
Vibrio fluvialis	*Vibrio fluvialis*

TABLE 25. SPECIES FOUND IN REFUSE-ONLY vs. INDUSTRIAL CODISPOSAL CELLS
Level B

REFUSE-ONLY CELLS	INDUSTRIAL CODISPOSAL CELLS
Clostridium botulinum	
	Clostridium limosum
Clostridium perfringens	*Clostridium perfringens*
	Clostridium ramosum
	Clostridium subterminale
Absidia	
	Allescheria boydii
Alternaria sp.	*Alternaria* sp.
Aspergillus sp.	*Aspergillus* sp.
Aspergillus flavus	
Aspergillus fumigatus	
Aspergillus niger	*Aspergillus niger*
Aureobasidium sp.	
Cephalosporium sp.	*Cephalosporium* sp.
Chaetomium sp.	
Cladosporium sp.	*Cladosporium* sp.
	Demphite sp.
Epicoccum sp.	
	Fonsecaea pedrosoi
	Monosporium apiospermum
Paecilomyces sp.	*Paecilomyces* sp.
Penicillium sp.	
	Phoma sp.
Rhodotorula sp.	*Rhodotorula* sp.
Sepedonium sp.	*Sepedonium* sp.
Trichophyton sp.	*Trichophyton* sp.
Yeast	Yeast

(continued)

TABLE 25. SPECIES FOUND IN REFUSE-ONLY vs. INDUSTRIAL CODISPOSAL CELLS
Level B (cont.)

REFUSE-ONLY CELLS	INDUSTRIAL CODISPOSAL CELLS
Acinetobacter calcoaceticus var. *lwoffi*	
	Aeromonas hydrophila
	Alcaligenes sp.
Citrobacter freundii	
	Enterobacter aerogenes
Enterobacter agglomerans	*Enterobacter agglomerans*
	Enterobacter cloacae
	Hafnia alvei
Klebsiella pneumonia	
	Klebsiella ozaenae
	Klebsiella oxytoca
	Moraxella kingii
Pseudomonas sp.	*Pseudomonas* sp.
Pseudomonas aeruginosa	
Vibrio fluvialis	*Vibrio fluvialis*
	Yersinia enterocolitica

TABLE 26. SPECIES FOUND IN REFUSE ONLY vs. INDUSTRIAL CODISPOSAL CELLS
Level C

REFUSE-ONLY CELLS	INDUSTRIAL CODISPOSAL CELLS
	Clostridium sp.
	Clostridium bifermentans
Clostridium botulinum (Group II)	*Clostridium botulinum* (Group I)
	Clostridium cadaveris
	Clostridium difficile
Clostridium histolyticum	
	Clostridium paraperfringens
Clostridium perfringens	*Clostridium perfringens*
	Clostridium sordellii
	Clostridium subterinale
	Allescheria boydii
	Alternaria sp.
Aspergillus sp.	*Aspergillus* niger
Aureobasidium sp.	
Cladosporium sp.	*Cladosporium* sp.
Fonsecaea sp.	
Gliocladium sp.	
Madurella mycetomi	
Monosporium sp.	*Monosporium apiospermum*
	Paecilomyces sp.
Penicillium sp.	*Penicillium* sp.
	Sepedonium sp.
	Trichophyton sp.
Yeast	Yeast
	Acinetobacter calcoaceticus var. anitratus
	Aeromonas hydrophila
Citrobacter freundii	
	Enterobacter agglomerans
	Enterobacter gergoviae
Hafnia alvei	
Pseudomonas sp.	*Pseudomonas maltophilia*
Serratia sp.	*Serratia fonticola*
Serratia liquefaciens	
Vibrio fluvialis	
	Yersinia intermedia

TABLE 27. SPECIES FOUND IN REFUSE ONLY vs. INDUSTRIAL CODISPOSAL CELLS
Diapers

REFUSE-ONLY CELLS	INDUSTRIAL CODISPOSAL CELLS
Clostridium perfringens	*Clostridium perfringens*
	Clostridium subterminale
Absidia sp.	
Alternaria sp.	*Alternaria* sp.
Aspergillus sp.	
Aspergillus flavus	
	Aspergillus niger
Aureobasidium sp.	
Cephalosporium sp.	
Chaetomium sp.	
Cladosporium sp.	*Cladosporium* sp.
Epicoccum sp.	
	Fonsecaea sp.
Paecilomyces sp.	*Paecilomyces* sp.
Penicillium sp.	*Penicillium* sp.
Rhodotorula sp.	
	Sepedonium sp.
	Trichophyton sp.
Yeast	
Acinetobacter calcoaceticus var. anitratus	*Acinetobacter calcoaceticus* var. anitratus
	Alcaligenes sp.
Enterobacter agglomerans	
Klebsiella pneumoniae	*Klebsiella pneumoniae*
	Klebsiella oxytoca
	Moraxella kingii
Pseudomonas sp.	
Vibrio fluvialis	

Methane Bacteria

A qualitative test for the presence of methane bacteria was performed by adding samples of decreasing weight from each sample level to a methanogenesis growth medium in closed test vials. The gas produced in each vial was then measured quantitatively by gas chromatograph for the percentage of carbon dioxide, oxygen, nitrogen and methane.

The absence of methane in the gas indicated the absence of methane-forming bacteria in the samples. The presence of methane indicated the presence of methane-forming bacteria in culture vials from all levels of all cells. A range of sample weights was evaluated (5.0 grams to 0.005 grams) to determine the wide or narrow distribution of methane-forming bacteria throughout the refuse. These tests indicated that the methane-forming bacteria were widely distributed in both the refuse-only and the codisposal cells. Methane was determined to be present in 113 vials out of the 120 sample vials tested. Six of the 113 produced enough gas to pop the lids of these vials and were therefore not analyzed for the percentage of methane present. Figures 15 to 24 depict the percentages of methane produced in each sample vial. Complete gas composition data for each sample analyzed can be found in Appendix A.

Absolute percentages of methane vary from cell to cell. This variation may be due to many factors which were either not measured or were not measurable. For example, the amount of substrate available to the bacteria in the small microbiological samples taken may have been limiting to the bacteria. The key point to be obtained from this data is that the methane bacteria were present in all levels of all cells.

METHANE PRODUCTION IN TEST FILES (REFUSE ONLY)

▨ 5.0 g ▨ 0.5 g ▨ 0.05 g ▨ 0.005 g

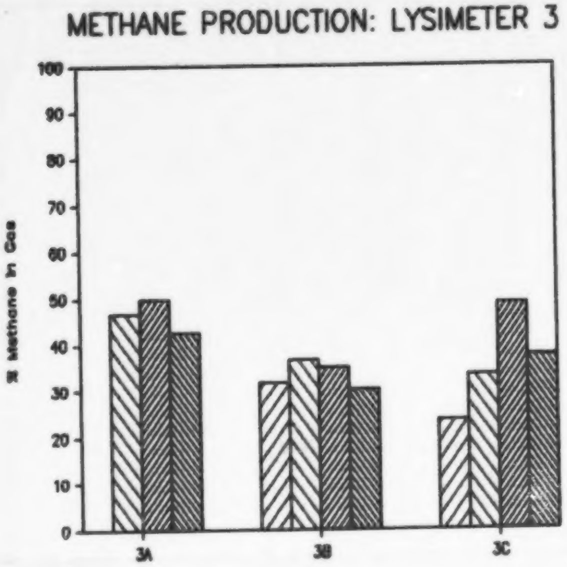

METHANE PRODUCTION: LYSIMETER 3

Figure 15

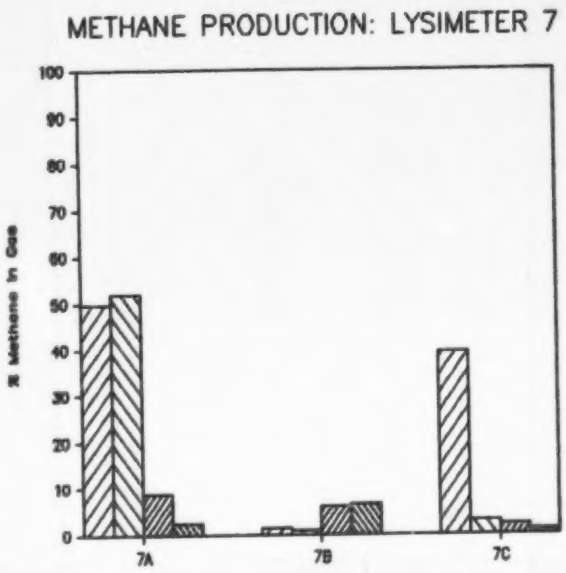

METHANE PRODUCTION: LYSIMETER 7

Figure 16

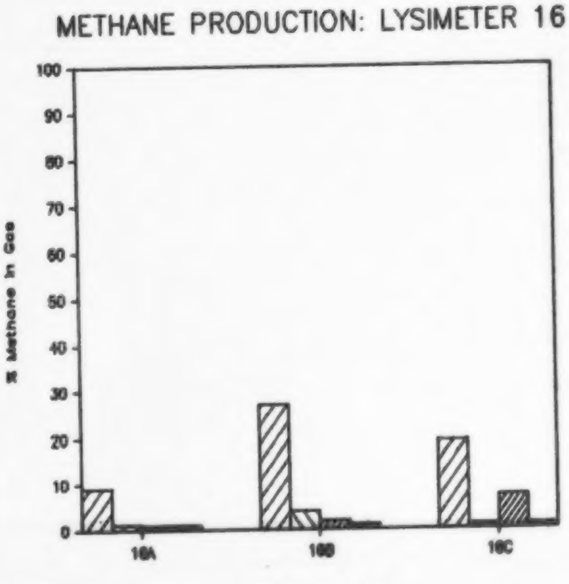

METHANE PRODUCTION: LYSIMETER 16

Figure 17

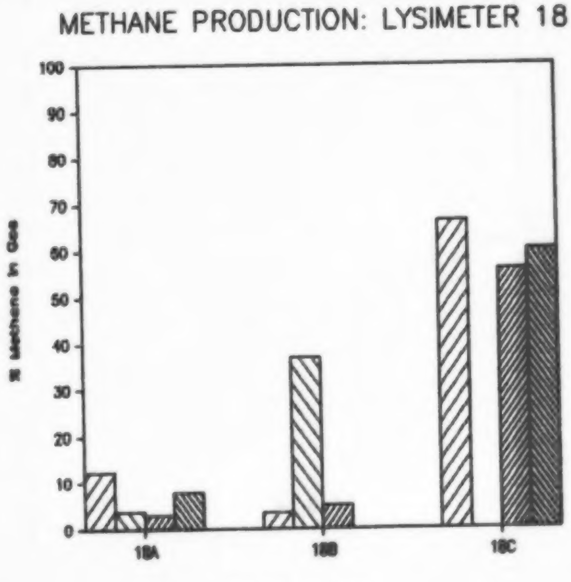

METHANE PRODUCTION: LYSIMETER 18

Figure 18

METHANE PRODUCTION IN TEST FILES (INDUSTRIAL CODISPOSAL)

▨ 5.0 g ▨ 0.5 g ▨ 0.05 g ▨ 0.005 g

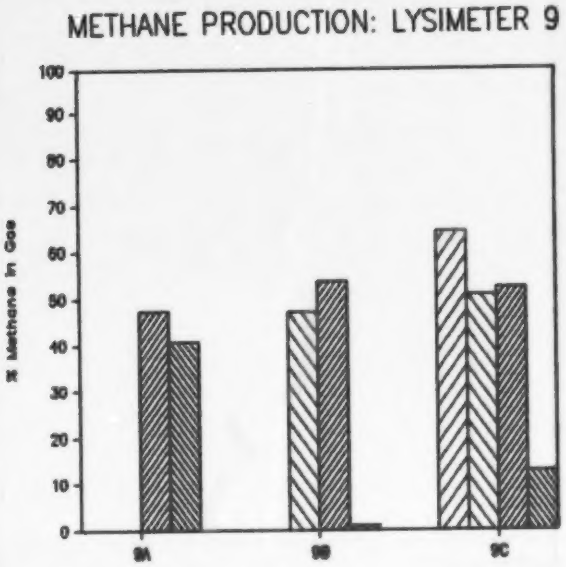


Figure 19

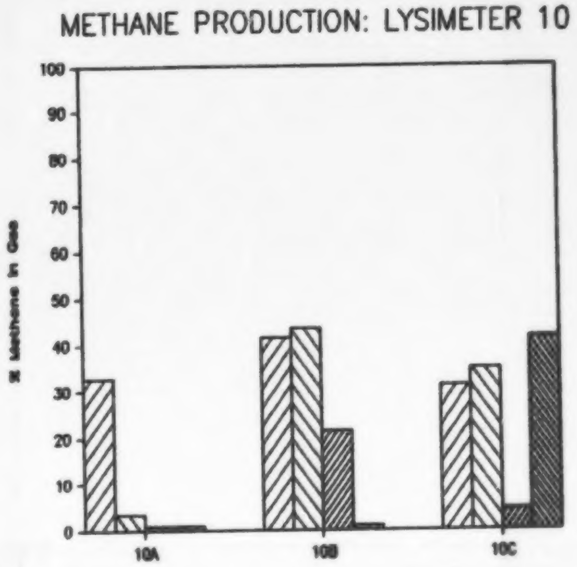


Figure 20

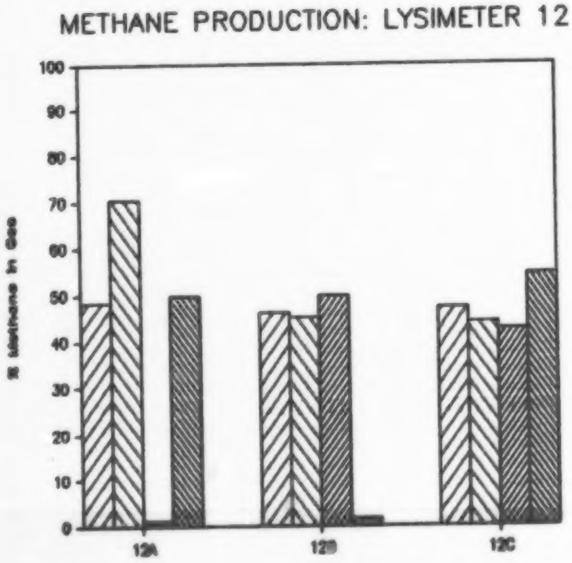


Figure 21

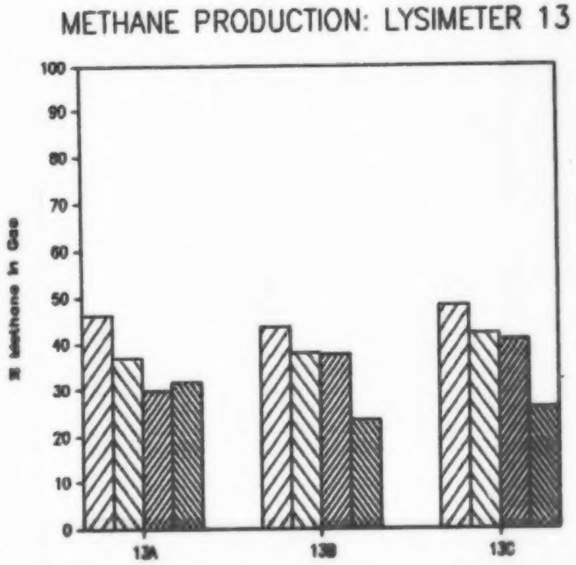


Figure 22

METHANE PRODUCTION IN TEST FILES (INDUSTRIAL CODISPOSAL) cont.

▨ 5.0 g ▧ 0.5 g ▨ 0.05 g ▩ 0.005 g

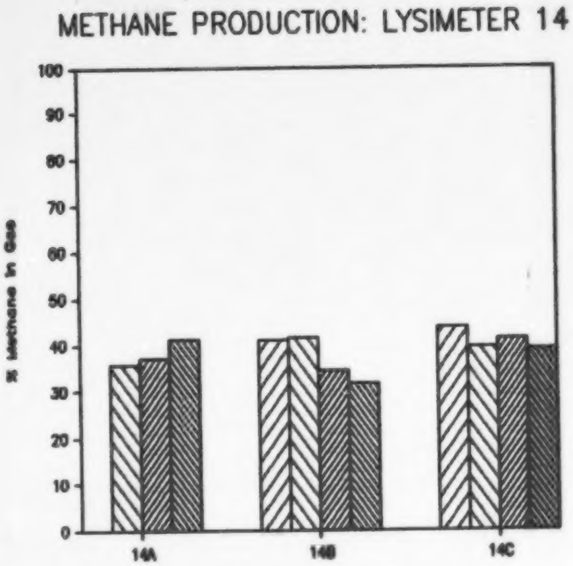


Figure 23

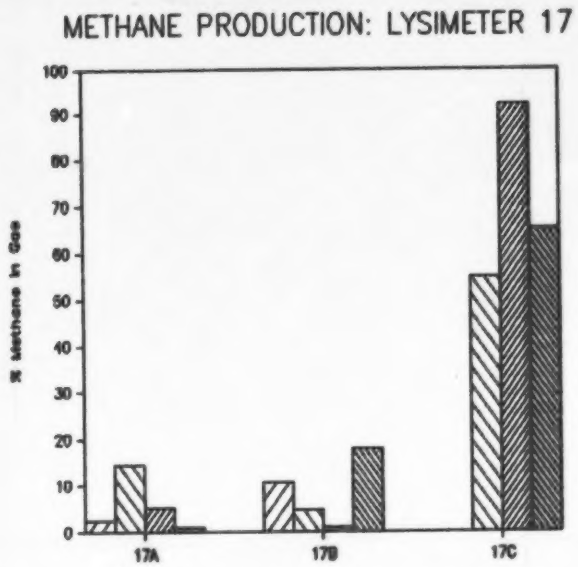


Figure 24

Comparison of Organisms in the Refuse-Only Cells

The following discussion describes specific microorganisms identified from each lysimeter. The tables associated with this discussion list the most prevalent species identified at each sample level within a given test cell. It should be noted that the species which have been identified represent only about 20 percent of the total different colonies which were observed. There is little replication of species from sample level to sample level and from cell to cell, which is probably largely due to the subjective selection of colonies for identification. The key objective in performing the identifications was to obtain summary information on the types of organisms predominating the lysimeters (pathogenicity, aerobic vs. anaerobic, etc.), rather than comprehensive identifications of all species present in the refuse.

Lysimeter 3

At Level A several strictly aerobic bacteria were most predominant. Acinetobacter calcoaceticus var. lwoffi and var. anitratus were at $9x10^9$ and $1x10^9$, respectively. Two facultative anaerobes, Citrobacter freundii and Enterobacter cloacae, were present in the next highest levels. These levels were $3x10^7$ and $1x10^7$, respectively.

TABLE 28. PREDOMINANT SPECIES AT EACH SAMPLE LEVEL (LYSIMETER 3)

MICROORGANISMS IDENTIFIED

Sample Level	Microbial Identification	Organism Type C: Clostridium F: Fungi G: Gram Negative Rod	Concentration (CFU/100g wet)
Sample Level A	*Acinetobacter calcoaceticus var. lwoffi*	G	$9x10^9$
	Acinetobacter calcoaceticus var. anitratus	G	$1x10^9$
	Enterobacter cloacae	G	$7x10^7$
	Acinetobacter sp.	G	$6x10^7$
	Citrobacter freundii	G	$3x10^7$
	Geotrichum sp.	F	$1x10^7$
	Scopulariopsis sp.	F	$1x10^7$
	Alcaligenes sp.	G	$1x10^7$
	Cephalosporium sp.	F	$4x10^6$
	Trichophyton sp.	F	$3x10^6$
	Monosporium sp.	F	$4x10^5$
	Paecilomyces sp.	F	$4x10^5$
	Syncephalastrum sp.	F	$4x10^5$
	Penicillium sp.	F	$1x10^5$
	Clostridium bifermentans	C	$1x10^4$
	Clostridium difficile	C	$1x10^4$
	Aspergillus fumigatus	F	$1x10^4$
Sample Level B (Diaper)	Pseudomonas sp.	G	$4x10^8$
	Enterobacter agglomerans	G	$1x10^8$
	Cladosporium sp.	F	$1x10^7$
	Pseudomonas aeruginosa	G	$1x10^7$
	Aureobasidium sp.	F	$6x10^6$
	Cephalosporium sp.	F	$1x10^5$
	Epicoccum sp.	F	$1x10^4$
Sample Level C	*Aspergillus* sp.	F	$1x10^6$
	Cladosporium sp.	F	$1x10^6$

Six different species of fungi were identified, with the most predominant species being *Geotrichum* and *Scopulariopsis*. These were both found at a concentration of $1x10^7$ CFU/100 grams wet weight.

At Level B only two bacterial species were identified, *Enterobacter asslomcrans* and a species of *Pseudomonas*. These two bacterial species also happened to be the most predominant species found at Level B, $4x10^8$ and $1x10^8$, respectively. Two species of fungi, *Cladosporium* sp. and *Aureobasidium* sp., were present in the next highest levels, which were found at concentrations of $1x10^7$ and $6x10^6$, respectively.

No bacterial species and only two species of fungi were identified at Level C. Both *Aspergillus* sp. and *Cladosporium* sp. were found at concentrations of $1x10^6$ CFU/100g wet weight.

Although there was the occurrence of two strictly anaerobic species in this test cell, general conditions through Cell 3 appear to favor aerobic microbes.

Lysimeter 7

At Level A, a mixture of bacterial organisms were present, including some strict aerobes, some facultative anaerobes, and a strict anaerobe. The numbers of these species favor aerobic conditions because the species, *Acinetobacter calcoaceticus* var. lwoffi ($9x10^9$ CFU/100g) was in highest numbers. The presence of other bacterial species, *Klebsiella pneumoniae*, *Serratia fonticola*, and *Hafnia alvei*, seem to indicate pockets of anaerobic conditions within the cell at this level.

Four fungal species were also at this level. The predominant fungus was *Trichophyton* sp. at a concentration of $1x10^9$ CFM/100g.

At Level B the two bacterial species identified were *Clostridium botulinum* (strict anaerobe) and *Citrobacter freundii* (facultative anaerobe). Thus, this sample indicated anaerobic conditions.

Four fungi species were present, but their concentrations decreased by one to four orders of magnitude from those at Level A. *Phoma* sp. was the predominate fungal species at this level at a $5x10^7$ CFU/100g concentration.

At Level C anaerobic conditions were present. The species found here were *Clostridium botulinum*, *Hafnia alvei* and *Serratia* sp., which are all anaerobes. (Level C was also the deepest sample of all samples taken in the test cells. The depth into the refuse was 92 inches (234 cm), which was near the refuse/bottom gravel interface.)

Five species of fungi were present at this level. The genus *Cladosporium* was identified as most prevalent at a concentration of $2x10^6$ CFU/100g.

TABLE 29. PREDOMINANT SPECIES AT EACH SAMPLE LEVEL (LYSIMETER 7)

MICROORGANISMS IDENTIFIED

Sample Level	Microbial Identification	Organism Type C: Clostridium F: Fungi G: Gram Negative Rod	Concentration (CFU/100g wet)
Sample Level A	*Acinetobacter calcoaceticus* var. *lwoffi*	G	9×10^{9}
	Trichophyton sp.	F	1×10^{9}
	Cladosporium sp.	F	5×10^{8}
	Trichoderma sp.	F	5×10^{8}
	Yeast	F	2×10^{8}
	Monosporium sp.	F	1×10^{8}
	Pseudomonas sp.	G	3×10^{7}
	Penicillium sp.	F	1×10^{7}
	Serratia fonticola	G	1×10^{7}
	Hafnia alvei	G	2×10^{6}
	Monosporium apiospermum	F	5×10^{5}
	Scopulariopsis sp.	F	5×10^{5}
	Madurella sp.	F	1×10^{5}
	Tatemella ptyseos	G	1×10^{5}
	Klebsiella pneumoniae	G	5×10^{4}
	Clostridium histolyticum	C	1×10^{4}
Sample Level B	*Phoma* sp.	F	5×10^{7}
	Clostridium botulinum	C	2×10^{7}
	Citrobacter freundii	G	1×10^{6}
	Cladosporium sp.	F	1×10^{6}
	Aspergillus fumigatus	F	6×10^{5}
	Trichophyton sp.	F	6×10^{5}
	Pencillium sp.	F	2×10^{5}
	Aspergillus niger	F	1×10^{5}
	Sepedonium sp.	F	1×10^{5}
Sample Level C	*Cladosporium* sp.	F	2×10^{6}
	Aureobasidium sp.	F	1×10^{6}
	Monosporium sp.	F	1×10^{6}
	Gliocladium sp.	F	1×10^{6}
	Penicillium sp.	F	7×10^{5}
	Clostridium botulinum	C	1×10^{4}
	Madurella mycetomi	F	1×10^{4}
	Yeast	F	1×10^{4}
	Serratia sp.	G	1×10^{4}
	Serratia liquefaciens	G	1×10^{4}

Lysimeter 16

Only fungi were identified in this cell. Species concentrations were generally lower than similar fungal concentrations in other test cells. The predominant species in the test cell at Level A was a species of *Aspergillus* at 1x10^6 CFU/100g. All other species at all levels were in concentrations of 10^3 to 10^4. The number of different species at each level was as follows: six species at Level A, seven species at Level B, and two species at Level C.

Lysimeter 18

As in test cell 7, there was a mixture of aerobic and anaerobic bacterial organisms at Level A. The most abundant species was *Vibrio fluvialis*, a facultative anaerobe (1x10^{10} CFU/100g). The next most abundant species were *Citrobacter freundii* (7x10^9 CFU/100g), another facultative anaerobe, and *Alcaligenes* sp. (5x10^9 CFU/100g), a strict aerobe. Also present, but in lesser numbers, were five *Clostridium* species in concentrations of 10^4 to 10^8 CFU/100g.

Three fungal microbes were identified at this level. *Cladosporium* sp. was found in concentrations as high as some of the bacterial species (5x10^8 CFU/100g).

TABLE 30. PREDOMINANT SPECIES AT EACH SAMPLE LEVEL (LYSIMETER 16)

MICROORGANISMS IDENTIFIED

Sample Level	Microbial Identification	Organism Type C: Clostridium F: Fungi G: Gram Negative Rod	Concentration (CFU/100g wet)
Sample Level A	*Aspergillus* sp.	F	1x10^6
	Absidia sp.	F	1x10^4
	Chaetomium sp.	F	1x10^4
	Cladosporium sp.	F	1x10^4
	Rhodotorula sp.	F	1x10^4
	Yeast	F	1x10^4
Sample Level B (Diaper)	*Paecilomyces* sp.	F	1x10^4
	Aspergillus sp.	F	1x10^4
	Rhodotorula sp.	F	6x10^3
	Absidia	F	1x10^3
	Chaetomium sp.	F	1x10^3
	Penicillium sp	F	1x10^3
	Yeast	F	1x10^3
Sample Level C	*Cladosporium* sp.	F	1x10^4
	Fonsecaea sp.	F	1x10^4

TABLE 31. PREDOMINANT SPECIES AT EACH SAMPLE LEVEL (LYSIMETER 18)

MICROORGANISMS IDENTIFIED

Sample Level	Microbial Identification	Organism Type C: Clostridium F: Fungi G: Gram Negative Rod	Concentration (CFU/100g wet)
Sample Level A	*Vibrio fluvialis*	G	$1x10^{10}$
	Citrobacter freundii	G	$7x10^{9}$
	Alcaligenes sp.	G	$5x10^{9}$
	Cladosporium sp.	F	$5x10^{8}$
	Clostridium hastiforme	C	$2x10^{8}$
	Fonsecaea compactum	F	$5x10^{7}$
	Clostridium perfringens	C	$9x10^{6}$
	Aspergillus niger	F	$1x10^{6}$
	Clostridium histolyticum	C	$2x10^{5}$
	Clostridium botulinum	C	$1x10^{4}$
	Clostridium novyi	A	$1x10^{4}$
	Epidermophyton flococcum	F	$1x10^{4}$
	Paecilomyces sp.	F	$1x10^{4}$
	Penicillium sp.	F	1x104
Sample Level B (Diaper)	*Vibrio fluvialis*	G	$4x10^{9}$
	Pseudomonas sp.	G	$1x10^{9}$
	Acinetobacter calcoaceticus var. *lwoffi*	G	$2x10^{8}$
	Cephalosporium sp.	F	$1x10^{8}$
	Cladosporium sp.	F	$1x10^{8}$
	Klebsiella pneumoniae	G	$7x10^{7}$
	Aspergillus flavus	F	$1x10^{6}$
	Penicillium sp.	F	$5x10^{5}$
	Alternaria sp.	F	$1x10^{5}$
	Clostridium perfringens	C	$1x10^{4}$
Sample Level C	*Vibrio fluvialis*	G	$2x10^{9}$
	Pseudomonas sp.	G	$5x10^{8}$
	Penicillium sp.	F	$1x10^{8}$
	Citrobacter freundii	G	$5x10^{7}$
	Clostridium histolyticum	C	$3x10^{6}$
	Clostridium perfringens	C	$1x10^{6}$

At Level B, the species of bacteria present were as variable as at Level A. Again, the predominant species was *Vibrio fluvialis* at a concentration of $4x10^{9}$ CFU/100g. Two strict aerobes were found in the next highest concentrations. These were a species of *Pseudomonas* at $1x10^{9}$ CFU/100g and *Acineto-*

bacter calcoaceticus var. lwoffi at 2×10^8 CFU/100g. Only one of the five *Clostridium* species found in Level A (*C. perfringens*) was identified in Level B, and it was found in much lower concentrations than other species at that level (1×10^4 CFU/100g).

Two species of fungus were identified at concentrations similar to the *Acinetobacter* levels. They were *Cephalosporium* and *Cladosporium* (both found at concentrations of 1×10^8 CFU/100g).

These samples (A and B) were taken at a relatively shallow position into the refuse (12" and 24", respectively), which probably accounts for some of the variability and high concentrations.

At Level C, *Vibrio fluvialis* was once again found to be the predominant species. The concentration found, 2×10^9 CFU/100g, was similar to concentrations found in Levels A and B. Another facultative anaerobe, *Citrobacter freundii*, was also found at relatively high concentrations, 5×10^7 CFU/100g, at this level. A species of *Pseudomonas*, a strictly aerobic bacteria, as well as *Clostridium histolyticum*, a strict anaerobe, were also found in similar concentrations, 5×10^8 and 5×10^7 CFU/100g, respectively. This indicates pockets of aerobic and anaerobic conditions at this level.

The only fungi identified at this level, *Pencillium* sp., was found at a concentration of 1×10^8 CFU/100g.

TABLE 32. PREDOMINANT SPECIES AT EACH SAMPLE LEVEL (LYSIMETER 9)

MICROORGANISMS IDENTIFIED

Sample Level	Microbial Identification	Organism Type C: Clostridium F: Fungi G: Gram Negative Rod	Concentration (CFU/100g wet)
Sample Level A	*Aspergillus nidulans*	F	$4x10^6$
	Monosporium apiospermum	F	$1x10^6$
	Cephalosporium sp.	F	$6x10^5$
	Penicillium sp.	F	$2x10^4$
	Aspergillus sp.	F	$1x10^4$
	Nigrospora sp.	F	$1x10^4$
Sample Level B	*Cephalosporium* sp.	F	$1x10^7$
	Clostridium perfringens	C	$5x10^6$
	Monosporium apiospermum	F	$3x10^6$
	Cladosporium sp.	F	$2x10^6$
	Clostridium ramosum	C	$1x10^6$
Sample Level C	Serratia *fonticola*	G	$5x10^7$
	Penicillium sp.	F	$9x10^6$
	Yeast	F	$7x10^6$
	Aeromonas *hydrophila*	C	$6x10^6$
	Monosporium apiospermum	F	$2x10^6$
	Clostridium perfringens	C	$1x10^6$
	Clostridium paraperfringens	C	$1x10^5$
	Clostridium sordellii	C	$1x10^5$

Lysimeter 9

At Level A, only fungi were identified. Six species were found. The highest concentrations were determined in the species *Aspergillus nidulans* ($4x10^6$ CFU/100g), *Monosporium apiospermum* ($1x10^6$ CFU/100g) and *Cephalosporium* sp. ($6x10^5$ CFU/100g).

At Level B, the bacterial microorganisms present indicated anaerobic conditions. *Clostridium perfringens* and *Clostridium ramosum* were found at concentrations of $5x10^6$ and $1x10^6$ CFU/100g, respectively. The fungus *Cephalosporium* sp. was the predominant species at this level, found at a concentration of $1x10^7$ CFU/100g.

At Level C, anaerobic conditions were present. Three species of *Clostridium* were present (all strict anaerobes). *Aeromonas hydrophila* and *Serratia fonticola* (both facultative anaerobes) were also identified, the latter being the most prevalent species ($5x10^7$ CFU/100g). Three fungi were identified. *Penicillium* sp. had the highest concentration at $9x10^6$ CFU/100g.

Lysimeter 10

The fungi were at all levels within this test cell. Two species were found at Level A, four species were identified at Level B, and three species were identified at Level C. *Sepedonium* sp. was the only species found at each level and was also found in the highest concentration for all fungi at all levels (10^{6}-10^{7} CFU/100g).

The bacterial species present were in greater concentrations than the fungal species at Levels B and C. The predominant species at Level B was *Pseudomonas* sp. at a concentration of 1x10^{4} CFU/100g. This dominance changed at Level C, where the species *Enterobacter gergoviae* was found in concentrations of 1x10^{9} CFU/100g. These species indicate more favorable aerobic conditions at Level B, while anaerobic conditions were more prevalent at Level C.

TABLE 33. PREDOMINANT SPECIES AT EACH SAMPLE LEVEL (LYSIMETER 10)

MICROORGANISMS IDENTIFIED

Sample Level	Microbial Identification	Organism Type C: Clostridium F: Fungi G: Gram Negative Rod	Concentration (CFU/100g wet)
Sample Level A	*Cephalosporium* sp.	F	1x10^{6}
	Sepedonium sp.	F	1x10^{6}
Sample Level B	*Pseudomonas* sp.	G	1x10^{9}
	Yersinia enterocolitica	G	3x10^{7}
	Sepedonium sp.	F	4x10^{6}
	Alternaria sp.	F	1x10^{5}
	Allescheria boydii	F	2x10^{4}
	Rhodotorula	F	1x10^{4}
Sample Level C	*Enterobacter gergoviae*	G	1x10^{9}
	Yersinia intermedia	G	5x10^{8}
	Klebsiella pneumoniae	G	8x10^{7}
	Sepedonium sp.	F	1x10^{7}
	Penicillium sp.	F	1x10^{6}
	Allescheria boydii	F	2x10^{4}

Lysimeter 12

At Level A, two species of *Clostridium* (*C. sordellii* and *Clostridium perfringens*) were present at concentrations of $5x10^6$ and $6x10^5$ CFU/100g, respectively. A fungal-yeast species was also identified at a concentration of $2x10^5$ CFU/100g.

At Level B, the bacterial species *Hafnia alvei*, a facultative anaerobe, predominated at a concentration of $1x10^9$ CFU/100g. This was four orders of magnitude higher than the next most abundant species, a fungus (*Demphite*).

At Level C, anaerobic conditions were prevalent, but with pockets of aerobic conditions, according to the microbial bacteria present. Six species of *Clostridium* (strict anaerobes) were identified in concentrations of 10^6 -10^8 CFU/100g. Three gram negative rods were present. Two of these, *Hafnia alvei* and *Aeromonas hydrophila*, are facultative anaerobes. The other species, *Pseudemonas maltophilia*, is a strict aerobe. *Cephalosporium* sp. was the only fungus at this level, at a concentration of $1x10^5$ CFU/100g.

TABLE 34. PREDOMINANT SPECIES AT EACH SAMPLE LEVEL (LYSIMETER 12)

MICROORGANISMS IDENTIFIED

Sample Level	Microbial Identification	Organism Type C: Clostridium F: Fungi G: Gram Negative Rod	Concentration (CFU/100g wet)
Sample Level A	*Clostridium sordellii*	C	$5x10^6$
	Clostridium perfringens	C	$6x10^5$
	Yeast	F	$2x10^5$
Sample Level B	*Hafnia alvei*	G	$1x10^9$
	Demphite	F	$1x10^5$
	Yeast	F	$4x10^4$
Sample Level C	*Clostridium* sp.	C	$1x10^8$
	Clostridium botulinum	C	$1x10^8$
	Hafnia alvei	G	$5x10^7$
	Aeromonas hydrophila	G	$5x10^7$
	Pseudomonas maltophilia	G	$4x10^7$
	Clostridium cadaveris	C	$1x10^7$
	Clostridium perfringens	C	$9x10^6$
	Clostridium difficile	C	$8x10^6$
	Clostridium bifermentans	C	$8x10^6$
	Cephalosporium sp.	F	$1x10^5$

TABLE 35. PREDOMINANT SPECIES AT EACH SAMPLE LEVEL (LYSIMETER 13)

MICROORGANISMS IDENTIFIED

Sample Level	Microbial Identification	Organism Type C: Clostridium F: Fungi G: Gram Negative Rod	Concentration (CFU/100g wet)
Sample Level A (Diaper)	*Clostridium perfringens*	C	$4x10^{7}$
	Paecilomyces sp.	F	$2x10^{7}$
	Klebsiella pneumoniae	G	$2x10^{7}$
	Cladosporium sp.	F	$5x10^{6}$
	Sepedonium	F	$2x10^{6}$
	Trichophyton sp.	F	$6x10^{4}$
	Yeast	F	$2x10^{5}$
Sample Level B	*Sepedonium* sp.	F	$3x10^{6}$
	Aspergillus sp.	F	$1x10^{6}$
	Paecilomyces sp.	F	$1x10^{6}$
	Phoma sp.	F	$1x10^{6}$
	Clostridium perfringens	C	$5x10^{5}$
	Clostridium limosum	C	$5x10^{4}$
	Enterobacter aerogenes	G	$3x10^{4}$
	Enterobacter agglomerans	G	$1x10^{4}$
Sample Level C	*Clostridium perfringens*	C	$5x10^{5}$
	Clostridium bifermentans	C	$7x10^{4}$
	Paecilomyces sp	F	$1x10^{5}$
	Sepedonium sp.	F	$1x10^{5}$
	Enterobacter agglomerans	G	$2x10^{4}$

Lysimeter 13

At Level A, *Klebsiella pneumoniae*, a facultative anaerobe, was found in concentrations of $2\text{-}3x10^{7}$ CFU/100g. *Clostridium perfringens*, a strict anaerobe, was identified at a $4x10^{7}$ CFU/100g concentration. A number of fungal species were found at this level. Five species in total were identified. The fungi, *Cladosporium* sp. and *Sepedonium* sp., were found in the highest concentrations at $5x10^{6}$ and $2x10^{6}$ CFU/100, respectively.

At Level B, four fungal species were identified at a concentration of $1\text{-}3x10^{6}$ CFU/100g. Two species, each of the Genus *Clostridium* and the genus *Enterobacter* were present, but both at a two- to three-fold reduction in concentration from Level A.

A species of Clostridium, *C. perfringens*, was at the highest concentration ($5x10^5$ CFU/100g) at Level C. Two fungi, Paecilomyces sp. and Sepedonium sp. were also present at a concentration of $1x10^5$ CFU/100g. The only gram negative rod was Enterobacter agglomerans. These organisms indicated anaerobic conditions at this level of the cell.

TABLE 36. PREDOMINANT SPECIES AT EACH SAMPLE LEVEL (LYSIMETER 14)

MICROORGANISMS IDENTIFIED

Sample Level	Microbial Identification	Organism Type C: Clostridium F: Fungi G: Gram Negative Rod	Concentration (CFU/100g wet)
Sample Level A	Vibrio fluvialis	G	$1x10^8$
	Penicillium sp.	F	$3x10^6$
	Trichophyton sp.	F	$2x10^6$
	Clostridium botulinum	C	$8x10^4$
	Aspergillus flavus	F	$1x10^4$
	Rhizopus sp.	F	$1x10^4$
Sample Level B	Enterobacter cloacae	G	$1x10^9$
	Klebsiella ozaenae	G	$1x10^8$
	Vibrio fluvialis	G	$1x10^8$
	Aeromonas hydrophila	G	$1x10^7$
	Enterobacter agglomerans	G	$6x10^7$
	Trichophyton	F	$1x10^6$
	Aspergillus niger	F	$1x10^4$
Sample Level C	Trichophyton sp.	F	$2x10^6$
	Penicillium sp.	F	$1x10^6$
	Clostridium bifermentans	C	$1x10^4$

Lysimeter 14

At Level A, Vibrio fluvialis, a facultative anaerobe, was present in the highest concentration ($1x10^8$ CFU/100g). Four fungi species were identified. Of those, Penicillium sp. and Trichophyton sp. were in the highest concentrations ($3x10^6$ and $2x10^6$ CFU/100g, respectively).

Level B showed a shift in species dominance from the fungi to the gram negative rods. Five species of gram negative rods were identified, compared to two fungi. Of those species present, Enterobacter cloacae, a facultative anaerobe, was in the highest concentration at $1x10^9$ CFU/100g.

Another shift in species occurred at Level C. Two fungi genuses, Trichophyton and Penicillium, were identified at a concentration in the 10^6 CFU/100g range. The only other microbe found was Clostridium bifermentans at a concentration of 1×10^4 CFU/100g.

TABLE 37. PREDOMINANT SPECIES AT EACH SAMPLE LEVEL (LYSIMETER 17)

MICROORGANISMS IDENTIFIED

Sample Level	Microbial Identification	Organism Type C: Clostridium F: Fungi G: Gram Negative Rod	Concentration (CFU/100g wet)
Sample Level A	Klebsiella oxytoca	G	4×10^9
	Enterobacter cloacae	G	3×10^9
	Pseudomonas sp.	G	4×10^8
	Cladosporium sp.	F	2×10^5
	Penicillium sp.	F	1×10^5
	Absidia	F	1×10^4
	Yeast	F	1×10^4
Sample Level B (Diaper)	Alcaligenes sp.	G	7×10^9
	Klebsiella oxytoca	G	2×10^8
	Moraxella kingii	G	2×10^8
	Fonsecaea pedrosoi	F	1×10^7
	Paecilomyces sp.	F	1×10^6
	Penicillium sp.	F	5×10^5
	Cladosporium sp.	F	1×10^5
	Clostridium subterminale	C	1×10^3
Sample Level C (Diaper)	Acinetobacter calcoaceticus var. anitratum	G	5×10^7
	Aspergillus niger	F	1×10^6
	Cladosporium sp.	F	5×10^5
	Alternaria sp.	F	1×10^4
	Clostridium subterminale	C	1×10^3

Lysimeter 17

Three bacterial species were identified at Level A. Two were facultative anaerobes, Klebsiella oxytoca and Enterobacter cloacae. The other species was of the genus Pseudomonas, a strict aerobe. All three species had concentrations of 10^8-10^9 CFU/100g.

Four fungal species were identified at Level A, but all were at least at a four-fold concentration less than any of the bacterial species. Cladosporium sp. was in the highest concentration at $2x10^5$ CFU/100g.

At Level B, species present indicated aerobic conditions with pockets of anaerobic conditions. Two strict aerobes, Alcaligenes sp. and Moraxella kingii, were found in concentrations of 7.10^9 and $2x10^8$ CFL/100g, respectively. A facultative anaerobe, Klebsiella oxytoca, was found in concentrations of $2x10^8$. Two fungal species, Fonsecaea pedrosoi and Paecilomyces sp. were identified. Their concentrations were one to two orders of magnitude lower than the bacterial species.

At Level C, Clostridium subterminale, a strict anaerobe, was identified at a concentration of 10^3 CFU/100g. The other bacterial organism found was Acinetobacter calcoaceticus var. anitratum, a strict aerobe, at $5x10^7$ CFU/100g. Since this was the greater species concentration, aerobic conditions must have been prevalent, with pockets of an anaerobic environment also occurring.

Three fungi were found at Level C. The most prevalent was Aspergillus niger at a concentration of $1x10^6$ CFU/100g.

Summary

Comparisons of microorganisms within the refuse-only cells versus the industrial/refuse cells show no strong characteristic differences. The diapers evaluated from the lysimeters generally had organism levels and species similar to refuse samples. The number of species for each of the three general microbe groups (gram positive microbes, gram negative microbes, and the fungi) indicated no large differences between cells. The concentrations of organisms generally decrease the greater the cell depth. There seemed to be no dominant species from cell to cell at any of the three sample levels. Different species demonstrated dominance in each test cell and at different levels.

Species occurrence was similar for both types of cells except for the gram negative organisms (however, no species strongly dominated in any of the cells). The genus Clostridium was in all but two cells. Aspergillus, Penicillium, Cladosporium and Yeasts were the fungal genuses most often identified in both types of cells. The most common gram negative organism to both cells was the genus Klebsiella. Other than this genus, the gram negative organisms occuring most frequently in the refuse-only cells were Citrobacter freundii, Alcaligenes sp., Acinetobacter sp., and Pseudomonas sp. Those in the industrial/refuse cells were Aeromonas hydrophila and Enterobacter sp.

The numbers and types of organisms throughout the cells indicate random variability of conditions depending, we feel, on the placement of refuse within the test cell. That is, the variability of the substrate (refuse) and moisture within the cell (again because of plastic bag protection) both affected species' variability and presence.

Some of the organisms identified are known pathogens. Table 38 shows the pathogenic species identified in the refuse and describes the diseases associated with the organisms. The presence of these pathogenic organisms has significant implications with respect to reuse of closed landfill sites. At a minimum, precautions should be taken during construction on such sites. Further research should be performed to evaluate the movement of those pathogens in the landfill and their release to the environment via leachate.

PERMEABILITY

There are few in-place hydraulic conductivity data currently available on municipal solid waste. Obtaining this information could be helpful in understanding and interpreting flow rates and the hydraulic properties of MSW, so that better estimates of water flow through landfills can be made. Such data might also be useful in projecting the integrity of landfill cover systems and the consequences of potential failures. With these applications in mind, the permeability of the waste was determined for test cells 1, 2, 4, and 16. Test cell 16 was examined, both with the clay layer in place and with the clay layer removed. These particular cells were selected because they were all filled with municipal refuse only and represented the major variations in the study that would affect permeability.

Test cell 2 received a moderate amount of infiltration water and was considered the primary control cell. Therefore, this cell provided some basis for comparison. Test cell 1 had the least moisture added while test cell 4 had the most moisture added. Test cell 16 received the same amount of moisture addition as cell 2, however, it was located inside the Center Hill high bay. Therefore, cell temperatures were routinely higher than in the other cells (cells 1, 2 and 4 were located outside).

The permeability measurement was replicated three times for each cell. The permeability measurement on cell 16 was performed with the clay layer in place and then repeated with the clay layer removed. The mean permeability of cell 16 with the clay layer in place was 1.05×10^{-2}, and the mean permeability of the refuse with the clay layer removed was 1.03×10^{-2}. As the cell contents, both clay and refuse, were completely saturated at the time of permeability testing, the similarity of permeability with the clay layer in place and the clay layer removed is not surprising. Since similar results were obtained in both situations, the permeability of the remaining three test cells was determined with the clay layer in place. Permeabilities obtained with the clay layer in place can be seen in Table 39.

Permeabilities of this absolute magnitude are commonly found in sands and gravels, although it is important to remember that reported permeability data usually are derived from laboratory measurements with one foot of constant hydraulic head. These measurements were determined with constant head of from 2.3 to 3.6 feet, depending on the cell in question. The constant head was determined by the depth of refuse from the infiltration line which was used as the overflow device to maintain constant head. Head was maintained within ±0.75 inches of the stated value.

TABLE 38. PATHOGENIC ORGANISMS IDENTIFIED IN REFUSE

ORGANISM		DISEASE [a,b,c]
Clostridium	*C. bifermentans*	gas gangrene (wounds)
	C. botulinum	food poisoning infant botulism
	C. difficile	fatal diarrhea
	C. histolyticum	gas gangrene
	C. novyi	gas gangrene
	C. perfringens	food poisoning gas gangrene
	C. ramosum	intra-abdominal infections
Fungi	*Aspergillus fumigatus*	pulmonary aspergillosis
	Aspergillus niger	fungus-ball (lungs) swimmers ear
	Aureobasidium sp.	allergies
	Monosporium apoispermum	mycetoma
	Madurella sp.	pulmonary infection mycetoma
	Trichophyton sp.[d]	ringworm
	Fonsecaea sp.	chromomycosis
	Epidermophyton floccosum	skin and nail infections
	Aspergillus nidulans	mycetoma
	Aspergillus flavus	pulmonary aspergillosis
Gram Negative Rods	*Aeromonas hydrophila*	wound infections diarrhea
	Klebsiella pneumoniae	wound infections
	Klebsiella ozaenae	wound infections
	Acinetobacter sp.	meningitis and septicienum
	Moraxella kingii	wound infections
	Yersinia enterocolitica	gastroenteritis mesenteric adenitis
	Yersinia intermedia	gastroenteritis mesenteric adenitis
	Alcalcigenes sp.	urinary tract infections

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a Davis et al. (1980)
b Koneman et al (1983)
c Lennette et al (1980)
d Pathogenic species

TABLE 39. COEFFICIENTS OF PERMEABILITY*

TEST CELL	K_1 (cm/sec)	K_2 (cm/sec)	K_3 (cm/sec)	MEAN K (cm/sec)	HEAD ft
1	1.33×10^{-2}	1.22×10^{-2}	1.24×10^{-2}	1.26×10^{-2}	2.3
2	1.15×10^{-2}	1.14×10^{-2}	1.13×10^{-2}	1.14×10^{-2}	2.3
4	1.05×10^{-2}	0.97×10^{-2}	0.98×10^{-2}	1.00×10^{-2}	2.8
16 w/clay	0.99×10^{-2}	1.05×10^{-2}	1.11×10^{-2}	1.05×10^{-2}	3.6
16 w/o clay	0.035×10^{-2}	0.98×10^{-2}	1.05×10^{-2}	1.02×10^{-2}	
Mean K w/clay	1.13×10^{-2}	1.10×10^{-2}	1.12×10^{-2}		

*Test was conducted with constant head. This head ranged from 2.3' to almost 3.6'. Each test cell head was fixed by the infiltration line elevation. This infiltration line served as the overflow pipe for a constant hydraulic head on the refuse mass.

There was more variation in the results between the lysimeters than within the replicates for a given lysimeter. However, these differences were not large enough to represent any significant difference in permeability.

Permeabilities would generally be expected to be lower in cells where more decomposition has occurred, since this would allow the refuse to become more compacted. Factors which would tend to increase decomposition, other than the actual refuse components, are moisture addition and temperature. Although the difference in permeabilities between cells was not significant in a practical sense, the data did behave in the anticipated manner. Cell 1, with the lowest moisture addition, had the highest permeability; cell 2, with a moderate moisture addition, had a slightly lower permeability; and cell 4, with the highest moisture addition, had the lowest permeability. Test cell 16, with the same moisture addition as cell 2 but with routinely higher temperatures, had a lower permeability than cell 2. These data are in complete agreement with anticipated results. However, as stated before, in practical applications, this difference was not appreciable.

Several conditions of the tests must be remembered for a meaningful comparison with full scale application. Great care was exercised here to remove all gases from the cells. This condition would be different in the full scale landfill. Water was added very slowly into the bottom leachate line to force the gases out through the top of the cells. Four days were required to fill the cells with water in this manner and attain complete saturation. In a full scale landfill, gases would be moving upward and outward from the point of origin and would tend to slow the movement of infiltration water into and through the refuse mass. This would lead to lower coefficients of permeability than those observed here.

A second condition, the level of constant head, was used because of the nature of the test cell design and construction, but this would be different from laboratory permeability measurements. Permeability is determined in the laboratory under standard conditions with a constant head of one foot. These measurements were made with a constant head of 2.3 feet for test cells 1 and 2, 2.8 feet for test cell 4, and 3.6 feet for test cell 16. Therefore, the head in these tests was from 2.3 to 3.6 times the normal laboratory head used for permeability determination.

Another difference in these tests which would be different from laboratory measurements, but which would more nearly simulate real landfills, was the fact that leachate was the fluid used to conduct these tests. Very pure laboratory water would be used in laboratory determinations of permeability on soils or gravels, but here leachate was used. Leachate would not behave the same as pure water because it would not be as viscous. Leachate viscosity would be lower than pure water because of the surface active organics in the leachate. So its flow through various passages through the refuse would be faster than laboratory distilled water.

Under field conditions, flow would probably be under a falling hydraulic head situation, rather than the constant head employed here. Hence, care should be exercised when extrapolating to full field scale conditions. These tests indicated that under the conditions stated, leachate moves through the refuse rather quickly. Once field capacity, saturated conditions are reached, infiltration water would move rather quickly through a landfill and push leachate out about as fast as the water is added.

SPECIFIC YIELD

The specific yield provides information on the volume of leachate released by gravity from the saturated refuse in terms of the volume of the saturated refuse. This information is useful in relating the rate and volume of water which moves through a landfill under conditions of falling hydraulic head. Such data would be useful in the design of leachate treatment systems.

Although specific yield data on municipal solid waste are available, they are from small samples. The Center Hill lysimeters provided an opportunity to obtain data from larger sources and under controlled conditions. The specific yield of the four lysimeters can be seen in Table 40.

Test cell 1 had the highest specific yield, 6.37 ft^3/yd^3. It had received the lowest moisture application. Test cell 4 had the lowest specific yield, 3.20 ft^3/yd^3, and the highest moisture application.

It is important to keep in mind the conditions under which these values were obtained. The first is the hydraulic head. This head varied from about 6.5 feet to 7.8 feet, with discharge being under falling head hydraulic

TABLE 40. LEACHATE SPECIFIC YIELD

TEST CELL	TOTAL VOLUME Q (L)	TOTAL VOLUME Q (ft^3)	REFUSE VOLUME (yds^3)	SPECIFIC YIELD (ft^3/yds^3)
1	1370	48.38	7.59	6.37
2	1293	45.66	7.77	5.88
4	694	24.51	7.67	3.20
16	772	27.26	6.64	4.10

$$Y_T = \frac{Q}{V}$$

Y_T = specific yield (ft^3/yd^3)
Q = total volume (ft^3)
V = refuse volume (yd^3)

TABLE 41. LEACHATE PRODUCTION

	CELL 1	CELL 2	CELL 4	CELL 16
Refuse Volume (yd^3)	7.59	7.77	7.67	6.64
Short-Term Production				
Q, liters	703	575	367	632
T, hours	1.25	0.95	0.92	4.0
LP, $L/hr/yd^3$	74.1	77.9	52.0	23.8
Long-Term Production				
Q, liters	543	715	327	124
T, hours	20	47.5	117	9
LP, $L/hr/yd^3$	3.58	1.94	0.36	2.07
Total Leachate Production				
Q, liters	1370	1293	694	772
T, hours	78	50	117	44
LP, $L/hr/yd^3$	2.31	3.33	0.77	2.64

$$LP = \frac{\frac{Q}{T}}{V}$$

Q = volume
T = time
V = refuse volume

conditions. The total volume of refuse available to moisture (leachate) was saturated. Completely sealed, bagged materials would not be available to the leachate for saturation.

Secondly, the gases were removed from the refuse mass by upflow filling of the refuse mass, so gas would not have been able to interfere appreciably with the short-term flow of leachate from the mass. However, the long-term flow would have been influenced by gas production within the refuse mass. Gas bubbles were evident at all times during the permeability testing, so gas production was going on.

It is instructive to look at the short-term leachate production in terms of the refuse volume (see Table 41). The initial rate for test cell 1 was 74.1 L/hr/yd^3, while the rate for test cell 16 was 23.8 L/hr/yd^3. The rate for test cell 2 was 77.9 L/hr/yd^3, while the rate for test cell 4 was 52 L/hr/yd^3. Each of these rates reflects the pore conditions of the refuse mass, hydraulic head, and the respective ability of the refuse mass to hold water or release it.

There appeared to be considerable variability in this characteristic. Over time, the total leachate production was not as variable among the four cells evaluated. Three of the cells, 1, 2, and 16, were similar (2.31. 3.33, 2.64 L/hr/hd^3, respectively). Test cell 4 was much lower at 0.77 L/hr/yd^3. It appears the higher moisture application rate accelerated decomposition and produced a finer particle size mass that would retain water or leachate over a longer time period than those cells receiving less moisture.

CHANNELING

No visible evidence of channeling was noted except in test cell 9, where the petroleum sludge coated the material and kept it dry. A close look at the moisture content determined on three samples from each cell confirms this fact. Obviously, there was localized channeling around sealed bags of refuse and objects which were impermeable to leachate flow, such as auto tires or bricks.

The application rate of water into each test cell was as follows:

Test Cell	Application Rate (mm/yr)
1	200
2	400
3	600
4	800
5 - 19	400

Table 42 presents the "as sampled" moisture content data on a wet weight basis for test cells 1 - 19. Test cell 2 had the highest mean moisture content (58.65%) of the four cells with different application rates of water. This was probably due to the types of refuse materials available for moisture retention. The highest value at any sample point in the first four cells was

TABLE 42. SAMPLE MOISTURE CONTENT - AS SAMPLED
% Moisture (Wet Weight)

TEST CELL	A	B	C	MEAN
1	55.17	45.16	54.78	51.70
2	55.56	61.84	58.56	58.65
3	65.71	53.94	48.61	55.75
4	56.45	50.77	56.25	54.49
5	49.00	60.82	60.49	56.77
6	52.48	46.90	53.33	50.90
7	58.54	49.60	57.76	55.30
8	51.04	54.76	57.45	54.42
9	46.79	48.00	44.21	46.33
10	51.52	57.41	50.49	53.14
11	58.59	57.43	55.91	57.31
12	54.29	52.13	57.26	54.56
13	60.18	56.48	46.67	54.44
14	57.39	46.81	61.25	55.15
15	56.25	54.17	56.04	55.49
16	53.49	54.89	48.13	52.17
17	51.68	50.97	55.36	52.67
18	53.25	51.08	61.74	55.36
19	51.72	44.69	55.00	50.47
ALL CELL MEAN	54.69	52.47	54.69	53.95
INDUSTRIAL CELL MEAN	53.27	52.37	53.24	52.96
MUNICIPAL REFUSE ONLY CELL MEAN	55.52	52.52	55.55	54.53

recorded in Sample A, test cell 3 (65.71%), which had the third highest application rate. The lowest moisture content value for these cells was in test cell 1, Sample B (45.16%), which had the lowest water addition.

The industrial cells' mean moisture content was 52.96% (wet weight). The highest value for any one industrial cell was in test cell 14, Sample C, which was 61.25%. The lowest value was in test cell 9, Sample C, at 44.21%. Test cell 9 had the lowest mean moisture content value of 46.33%, while test cell 14 had the highest mean value of 55.15%. Test cell 9 had the lowest moisture content, probably because of the coating effect (noted when moving refuse) the petroleum sludge had on the refuse, resulting in less retention of water.

The refuse-only cells' mean moisture content was 54.53% (wet weight). The highest value for any one refuse-only cell with the same water application rate was in test cell 2, Sample B, at 61.84%. The lowest moisture value was recorded in test cell 19, Sample B, at 44.69%. Test cell 2 had the highest mean value (58.65%), while test cell 19 had the lowest mean value (50.47%).

Generally, industrial cells did not differ much in moisture content from refuse-only cells. Within any one cell the moisture content was variable and did not necessarily increase with depth of the cell, which may have been expected. This again was probably due to the location of cell refuse materials such as paper, leaves, etc., which have a greater capacity for retaining water.

Table 43 presents the moisture content on a dry weight basis for test cells 1-19. Test cell 2 had the highest mean moisture content (142.8%) of the four cells with different application rates of water. The highest value at any one sample point in the first four cells was in Sample A, test cell 3 (191.7%), which had the third highest water application rate. The lowest moisture content value for these cells was in test cell 1, Sample B (82.4%), which had the lowest water addition.

The industrial cells' mean moisture content was 114.7% (dry weight). The highest value for any one industrial cell was in test cell 14, Sample C, at 158.1%. The lowest value for the industrial cells was in test cell 9, Sample C, at 79.3%. Test cell 9 had the lowest mean moisture content (86.5%), while test cell 14 had the highest mean moisture content (126.9%). These data, therefore, followed the data generated from measurements on a wet weight basis.

The refuse-only cells' mean moisture content was 122.5% (dry weight). The highest value for any one refuse-only cell with the same application rate was in test cell 2, Sample B, at 162.1%. The lowest moisture content value was measured in test cell 19, Sample B, at 80.8%. Test cell 2 had the highest mean value (142.8%), while test cell 19 had the lowest mean value (103.4%). This again followed the measurements made on a wet weight basis.

Sufficient moisture was available throughout all the cells for decomposition to take place. There was no appreciable difference in moisture content to suggest that channeling of moisture around the refuse prevented decomposition.

TABLE 43. SAMPLE MOISTURE CONTENT - AS SAMPLED
% Moisture (Dry Weight)

TEST CELL	A	B	C	MEAN
1	123.1	82.4	121.2	108.9
2	125.0	162.1	141.3	142.8
3	191.7	112.5	94.6	132.9
4	129.6	103.1	128.6	120.4
5	96.1	155.3	153.1	134.8
6	114.9	88.3	114.3	105.8
7	141.2	98.4	136.7	125.4
8	104.3	121.1	135.0	120.1
9	87.9	92.3	79.3	86.5
10	106.3	134.8	102.0	114.4
11	141.5	134.9	126.8	134.4
12	118.8	108.9	134.0	120.6
13	151.1	129.8	87.5	122.8
14	134.7	83.0	158.1	126.9
15	128.6	118.2	127.5	124.8
16	115.0	121.7	91.8	109.5
17	106.9	103.9	124.0	111.6
18	113.9	104.4	161.4	126.6
19	107.1	80.8	122.2	103.4
ALL CELL MEAN	123.1	112.7	123.1	119.6
INDUSTRIAL CELL MEAN	115.7	111.3	117.1	114.7
MUNICIPAL REFUSE ONLY CELL MEAN	127.3	113.5	126.6	122.5

SEALS AND COAL TAR EPOXY CONDITION

Coal tar epoxy linings in all cells were in excellent condition. Test cell 2 had a few bubbles in the lining, but this was probably due to the application process during the lining. There appeared to be no effects from the ten-year-old exposure to both municipal solid waste and combined municipal solid waste and industrial sludges. Some coal tar epoxy was burned off during the lid removal procedure by the acetylene torch.

There were some differences in the top and bottom seals in the individual test cells, so a cell-by-cell discussion follows.

Test Cell No. 1 - Municipal Refuse Only

Top Seal. The top seal around the lid was in good condition. It appeared to be watertight, but not gas tight. Seals around the water infiltration line and gas and temperature probes appeared to have cracked because of weather conditions and age. The water infiltration valve would have leaked gas.

Bottom Seal. The bottom fiberglass seal was observed to be in good condition. The seal surface was even and relatively clean (free from hydrogen sulfide tarnishing) across the bottom of the tank. There was some slight bubbling on the sidewall of the tank. The seal on the tank sidewall could be pulled off quite easily, which occurred when the refuse was removed near the seal. The seal was still watertight.

Test Cell No. 2 - Municipal Refuse Only

Top Seal. The top seal around the lid was in good condition. It appeared to be watertight, but not gas tight. Seals around the water infiltration line, gas probes, temperature probes and the settlement tube appeared to have cracked because of weather conditions and age. Water infiltration valve would leak gas.

Bottom Seal. The bottom fiberglass seal was observed to be in good condition. The seal surface was even and relatively clean across the bottom of the tank. There was some slight bubbling on the tank's sidewall. It was observed when the refuse was removed near the seal on the tank sidewall that the seal could be easily removed. The seal was still watertight.

Test Cell No. 3 - Municipal Refuse Only

Top Seal. The top seal around the lid was in good condition. It appeared to be watertight, but was not. Water had entered around the lid and caused some corrosion of the sidewall. It was not gas tight. Seals around the water infiltration line, gas probes, temperature probes and settlement tube appeared to have cracked because of weather conditions and age. Gas would leak from the water infiltration valve.

Bottom Seal. The bottom fiberglass seal was observed to be in good condition. The seal surface was smooth and relatively clean across the bottom of the tank. There was some slight bubbling on the tank's sidewall. The seal on the tank sidewall could be pulled off, as observed when digging refuse near the seal. The seal was still watertight.

Test Cell No. 4 - Municipal Refuse Only

Top Seal. The top seal around the lid was in good condition. It appeared to be watertight, but not gas tight. Seals around the water infiltration line, gas probes, temperature probes, and settlement tube appeared to have cracked because of weather conditions and age. The water infiltration valve would leak gas.

Bottom Seal. The bottom figerglass seal was observed to be in good condition. The seal surface was even and relatively clean across the bottom of the tank. There was some slight bubbling on the tank's sidewall, but the seal did not pull off the sidewall as in test cells 1-3, even when digging refuse out near the seal. The seal was watertight.

Test Cell No. 5 - Municipal Refuse Plus Sewage Sludge

Top Seal. The top seal around the lid was in good condition. It appeared to be watertight, but it was not gas tight. Seals around the water infiltration line, gas probes, temperature probes and settlement tube appeared to have cracked because of weather conditions and age.

Bottom Seal. The bottom fiberglass seal was observed to be in good condition. The seal surface was even and relatively clean across the bottom of the tank. Some slight bubbling on the sidewall of the tank was noted. The sidewall seal could not be pulled off the tank when digging the refuse. The seal was watertight.

Test Cell No. 6 - Municipal Refuse Plus Sewage Sludge

Top Seal. The top seal around the lid was in good condition. It appeared to be watertight. but it was not gas tight. Seals around the water infiltration line, gas probes, temperature probes and settlement tube appeared to have cracked because of weather conditions and age.

Bottom Seal. The fiberglass bottom seal was observed to be in good condition. The seal surface was even and relatively clean across the bottom of the tank. There was some slight bubbling on the tank's sidewall, but the seal did not pull off the sidewall when digging the refuse out near the seal. The seal was watertight.

Test Cell No. 7 - Municipal Refuse Plus Sewage Sludge

Top Seal. The top seal around the lid was in good condition. It appeared to be watertight, but it was not gas tight. Seals around the water infiltration line, gas probes, temperature probes and settlement tube appeared to have cracked because of weather conditions and age.

Bottom Seal. The fiberglass bottom seal was observed to be in good condition. The seal surface was even and relatively clean across the bottom of the tank. There was very little bubbling noted on the tank's sidewall. The seal on the tank sidewall could be easily pulled off when digging the refuse out of the tank near the seal. The seal was watertight.

Test Cell No. 8 - Municipal Refuse Plus Calcium Carbonate Sludge

Top Seal. The top seal around the lid was in good condition. It appeared to be watertight, but it was not gas tight. This lid had a vent on it. Seals around the water infiltration line, gas probes and temperature probes appeared to have cracked because of weather conditions and age. Gas would leak from the water infiltration valve.

Bottom Seal. The fiberglass bottom seal was observed to be in good condition. The seal surface was even and relatively clean across the bottom of the tank with very little bubbling on the tank's sidewall. The seal on the tank sidewall did not pull off the sidewall when digging the refuse out near the seal.

Test Cell No. 9 - Municipal Refuse Plus Petroleum Waste Sludge

Top Seal. The top seal around the lid was open. This plywood lid had a vent on it and was neither water nor gas tight. Seals around the water infiltration line, gas probes and temperature probes appeared to have cracked because of weather conditions and age. Water infiltration valve would leak gas.

Bottom Seal. The fiberglass bottom seal was in poor condition. Although it was intact and watertight, considerable breakdown of the fibers was evident. Some compound appeared to have attacked the binding agent, resulting in the release of the fiber material. Considerable residue was on the bottom.

Test Cell No. 10 - Municipal Refuse Plus Battery Production Waste

Top Seal. The top seal around the lid was open. This plywood lid had a vent on it and was neither water nor gas tight. Seals around the water infiltration line, gas probes and temperature probes appeared to have cracked because of weather conditions and age. Gas would leak from the water infiltration valve.

Bottom Seal. The fiberglass bottom seal in this cell was observed to be in fair condition. The seal surface was rough across the bottom of the tank. Several places had bottom gravel stuck to this seal. The bottom was black, due to hydrogen sulfide staining, and not as easy to clean as in the first eight test cells. The sidewall seal had many bubbles, but still could not be pulled off the tank sidewall easily. Overall, the seal seemed to be affected by the waste and leachate contents that were placed in it or passed through it, respectively. The seal was watertight.

Test Cell No. 11 - Municipal Refuse Prewetted With Water

Top Seal. The top seal around the lid was in good condition. It appeared to be watertight, except at one location. It was not gas tight. Seals around the water infiltration line, gas probes, temperature probes and settlement tube cap appeared to have cracked because of weather conditions and age. The water infiltration valve would leak gas.

Bottom Seal. The fiberglass bottom seal was observed to be in poor condition. The seal surface was rough across the bottom of the tank. Bottom gravel stuck to the seal in several places. The bottom was clear except where the sidewall and bottom of the tank joined. Here, there was a blackening of the seal due to hydrogen sulfide tarnishing. The seal rose two to three inches up the tank sidewall as opposed to all seals in test cells 1 - 10, which were at least twelve inches up the tank sidewall. The result of this small amount of fiberglass seal up the sidewall was a peeling from the sidewall and splitting of the fiberglass in several places. The seal was watertight.

Test Cell No. 12 - Municipal Refuse Plus Electroplating Wastes

Top Seal. The top seal around the lid was open. The plywood lid had a vent on it and was neither gas nor watertight. Seals around the water infiltration line, gas probes and temperature probes appeared to have cracked because of weather conditions and age.

Bottom Seal. The fiberglass bottom seal was observed to be in poor conditon. The seal surface was rough across the bottom of the tank, where it had peeled up in several places. The bottom was dark, due to hydrogen sulfide tarnishing, and was not easy to clean as in the first eight test cells. The seal only rose three to four inches up the tank sidewall, much as in test cell 11. The result was a peeling from the sidewall and splitting of the fiberglass in several places. The seal was watertight.

Test Cell No. 13 - Municipal Refuse Plus Inorganic Pigment Waste

Top Seal. The top seal around the lid was open. The plywood lid had a vent on it, and it was neither gas nor watertight. Rainwater had carried earthworms into the cell. Seals around the water infiltration line, gas probes and temperature probes appeared to have cracked because of weather conditions and age. The water infiltration valve would leak gas.

Bottom Seal. The bottom fiberglass seal was observed to be in good condition. The seal surface was even and relatively clean across the bottom of the tank with some very slight bubbling on the sidewall of the tank. The seal on the tank sidewall could not be pulled off. It was watertight.

Test Cell No. 14 - Municipal Refuse Plus Chlorine Production Brine Sludge

Top Seal. The top seal around the lid was open. Water entered the cell and carried in earthworms. The lid was not gas tight. Seals around the water infiltration line, gas probes and temperature probes appeared to have cracked because of weather conditions and age.

Bottom Seal. The bottom fiberglass seal was observed to be in good condition. The seal surface was even and relatively clean across the bottom of the tank with some very slight bubbling on the sidewall of the tank. The seal on the tank sidewall could not be pulled off. The seal was watertight.

Test Cell No. 15 - Municipal Refuse With Polio Virus Addition

Top Seal. The top seal around the lid had many breaches. Considerable water entered this cell from the top and from leaks in the sidewall where the virus sample ports were not sealed. This cell always had over 500 liters of leachate, whether water was added or not. Water that entered from the top left trails down the sidewalls. Seals around the water infiltration line, gas probes and temperature probes appeared to have cracked because of weather conditions and age. Gas would leak from the water infiltration valve.

Bottom Seal. The bottom fiberglass seal was observed to be in good condition. The seal surface was a little rough across the bottom of the tank. About a quarter of the bottom was darkened due to hydrogen sulfide staining. There was some slight bubbling on the sidewall of the tank. The seal on the tank sidewall pulled off easily, which was observed when digging the refuse out of the tank near the seal. The seal was watertight.

(NOTE: Test cells 16 - 19 had no fiberglass seal on the bottom of the tank. All tanks had steel bottoms welded on with a drain in the center of each test cell bottom.)

Test Cell No. 16 - Muncipal Refuse Only

Top Seal. The top seal around the lid was in good condition. Seals around the temperature probes and gas probes showed some cracking. Water infiltration line seals also had some cracking. Gas could have leaked out here. The infiltration line valves leaked, so gas could have escaped here also.

Bottom Seal. The bottom of this cell was in excellent condition. It had a white-painted bottom which, when washed down, was quite clean and still white. The seal was watertight.

Test Cell No. 17 - Municipal Refuse Plus Solvent Base Paint Sludge

Top Seal. The top seal on this test cell differed from the other cells. A fiberglass and foam lip extended around the circumference of the welded lid so that a two-to-three-inch deep water seal was maintained on the lid. This appeared to be a good seal, but careful scrutiny revealed that gas was permeating through the fiberglass lip. This could have been caused by the solvents attacking the solvent binder of the double layers of fiberglass. Attempts were made to seal these during the study, but new openings would develop. Seals around the temperature probes, infiltration lines and gas probes showed cracking and possible leaks.

Bottom Seal. The bottom of the cell was in excellent condition. It had a white-painted bottom, which was evident upon rinsing down the test cell. The seal was watertight.

Test Cell No. 18 - Municipal Refuse Only

Top Seal. The top seal around the lid looked good. Seals around the temperature probes, gas probes and infiltration line and settlement tube had cracked. Gas could have leaked here. The infiltration valve also leaked, so gas could have escaped here as well.

Bottom Seal. The bottom of this cell was in excellent condition. It had a coal tar epoxy surface coat which showed no signs of deterioration. The seal was watertight.

Test Cell No. 19 - Municipal Refuse Only

Top Seal. The top seal around the lid could have leaked. Seals around the settlement tube, temperature probes, gas probes and water infiltration line had cracked. Gas could have leaked here. The infiltration valve also leaked.

Bottom Seal. The bottom of this cell was in excellent condition. It had a coal tar epoxy surface coat which showed no signs of deterioration. The seal was watertight.

EVALUATION OF LAYERS OF MSW AND INDUSTRIAL SLUDGES

There were no distinct layers of MSW-only items found in the refuse-only cells. At times there were pockets of specific items such as leaves, grass, tree limbs, a large rug, etc. This was typical and would be expected in a full-scale landfill. There were bags of various refuse items such as diapers, kitchen wastes, clothes, grass, leaves, cuttings, animal fecal matter, etc., which were sealed and protected from biological decomposition. These protected wastes were distributed in all the refuse-only cells and did not constitute a distinct layer. That is, they did not extend wall to wall in the lysimeter. There were no layers of separate material in the refuse-only cells. Everything was well-mixed throughout the refuse mass.

There were no distinct layers of industrial refuse in the combined cells except for the solvent-based paint sludge cell 17 and in the chlorine production brine sludge cell 14. In all of the others, there were pockets and small patches of the wastes, calcium carbonate, pigments, sewage sludge, petroleum sludge, etc., but there were no continuous layers wall to wall. Test cell 17 had continuous layers of paint sludge which appeared to have been little attacked by the microorganisms. These layers had items stuck to them which were then protected from biological decomposition. For example, chicken was protected by paint sludge in this cell.

Chlorine production brine sludge in cell 14 was found in partial layers still bagged. This material appeared to have suffered little attack by microbiological activity under the bagged conditions found. Nearby material was attacked by the biological activity and anaerobic conditions. The sludge did not protect materials from decomposition.

Petroleum sludge coated much of the material in test cell 9 and kept it dry. Nearby material which was not coated was attacked as vigorously as the material in the refuse-only cells. Many plastic and wooden items were coated with sludge and would not have been recognizable until the sludge was wiped off. This sludge had an oily, greasy consistency and tended to be difficult to remove. All of the conditions noted were photographed in black and white and in color.

ANALYSIS OF WASTE MATERIALS

Many items were recognizable and identified in all of the test cells. These artifacts were physically examined and noted as to condition. Many were placed in groups and then photographed. These artifacts documented the resistance to biological attack of plastic, paper, rubber, dyes, synthetic fabrics, bulk metal, plated metal, stainless steel, wood, glass, stone, and combinations of these materials.

Many other items which are readily biodegradable when exposed to attack were protected from biological activity. These items were noted in all test cells. Bread, corn on the cob, cheese, bacon, hot dogs, chocolate, chicken, steaks, ham, lunch meat, brats, carrots, beets, potatoes, sweet potatoes, coconut, candy, green grass, green leaves, oranges, grapefruits, and a host of other items which should be readily biodegradable were protected by plastic and paper wrappings. Human fecal matter and animal fecal matter were found in sealed plastic bags in disposable diapers and paper wrapping with the same appearance and consistency of fresh fecal matter. Very little change (decomposition) was noted. Appearance and odor were the same, which represented a dramatic finding after ten years. Newspapers and books could be read easily. The inks on paper and the dyes in clothes were very resistant to decomposition. Paints on metal and wood objects were protective of the bulk material and still very serviceable. Painted license plates, chairs, motors, etc., were protected from decomposition by the paint.

Plastic bags, waxed paper wrapping, and just many layers of wrapped paper prevented decomposition of many readily biodegradable items. These items appeared to have been protected such that they might have lasted in a full scale landfill indefinitely, at least fifty to one hundred years. This suggested that more recovery of certain items should be practiced and that our home disposal practices of sealing and wrapping many biodegradables with multiple layers of plastic and paper should be changed.

In addition to physical examination and photo documentation of the condition of the wastes, three samples of approximately fifty pounds each were taken from each test cell for moisture content, coarse grinding, fine grinding and chemical analysis. Tables 44,45,46,47,48, and 49 provide the data obtained in this manner. These data should not be directly compared with the initial refuse description analyses because the two analyses were carried out in different ways. The initial refuse analysis results were a composite of individual sort category analysis (COD of food wastes + COD of garden wastes + COD of paper, etc.) The final refuse analysis was conducted on three distinct samples removed from the test cell at three different locations. Final chemical analyses revealed a major fraction of organic material remaining after ten years.

In general, chemical analyses substantiated the results of the physical examination. Considerable carbon-containing materials remained in all cells. Mean TOC value for the six refuse-only cells (1,3,7,15,18 and 19) was 1270 g/kg on a dry weight basis, while the mean value for the six co-disposal cells (9,10,12,13,14 and 17) was 1260 g/kg on a dry weight basis. This was not a great difference and was probably due to the higher concentration of inorganic materials in the industrial sludges with the refuse. The mean TOC value for test cell 1 with the least moisture applied was 1320 g/kg on a dry weight basis, while the value for test cell 4 was 1250 g/kg. Test cell 4 had four times the moisture application rate, and hence, decomposition (carbon removal) was greater in test cell 4. Test cell 15, which received great quantities of water from the seals, had a mean TOC of 920 g/kg on a dry weight basis. This confirms that decomposition and/or physical removal of the carbon from the cell had proceeded much faster in this cell. Test cell 14 had the highest mean TOC, 1560 g/kg, while test cell 9 had the lowest, 877 g/kg on a dry weight basis for the co-disposal cells.

Mean COD values further substantiated the presence of considerable chemically oxidizable material in the cells after ten years. The mean COD value for the refuse-only cells was 1750 g/kg on a dry weight basis, while the mean COD value for the co-disposal cells was 1520 g/kg. This confirms that there was less chemically oxidizable material remaining in the co-disposal cells than in the refuse-only cells. Again, this could be due to less organic material in the original sludges placed in the cells.

Decomposition appeared to be the same for both co-disposal and refuse-only cells with the exception of test cell 15, where the excess water came into the cell. Mean COD for the low water cell 1 was 1570 g/kg, while the high water cell 4 had a mean COD of 1450 g/kg, which was significantly less than cell 1. Test cell 15 had a mean COD of 1340 g/kg, which was even lower than test cell 4. This confirmed again the more active decomposition caused by moisture.

TABLE 44. CHEMICAL ANALYSIS OF REFUSE (CELLS 1-8)
Dry

SAMPLE	IN PLACE REFUSE %MOISTURE	GROUND REFUSE %MOISTURE	COD g/kg dry	TOC g/kg dry	TKN g/kg dry	CL g/kg dry
1A	55.2	1.54	1910	1540	14.4	2.54
1B	45.2	1.65	800	847	8.41	1.47
1C	54.8	1.76	2000	1570	14.1	2.83
2A	55.5	6.58	2590	1750	20.3	3.11
2B	61.8	2.48	2940	2090	24.5	1.65
2C	58.6	3.45	2690	1900	23.9	2.71
3A	65.7	2.92	2660	2030	25.8	2.25
3B	52.9	1.82	1690	1310	13.6	1.67
3C	48.6	1.21	833	741	10.9	1.41
4A	56.5	2.61	1520	1250	17.8	2.25
4B	50.8	1.35	1200	1070	15.0	1.24
4C	56.3	2.07	1640	1420	19.3	1.56
5A	49.0	1.98	1760	1170	15.3	1.61
5B	60.0	2.34	2640	1700	14.9	1.72
5C	60.5	2.63	2370	2040	19.9	2.55
6A	52.5	2.63	1930	1380	13.0	2.07
6B	46.9	2.16	821	931	11.5	1.51
6C	53.3	2.33	2030	1700	9.40	2.32
7A	58.5	2.88	1810	1270	26.2	2.72
7B	49.6	2.13	1270	893	15.1	1.38
7C	57.8	1.50	2030	1620	12.8	3.61
8A	51.0	1.81	1420	1130	11.0	1.64
8B	54.8	3.32	2380	1820	12.6	3.27
8C	57.5	5.05	2960	2000	10.9	2.94

TABLE 45. CHEMICAL ANALYSIS OF REFUSE (CELLS 9-19)
Dry

SAMPLE	IN PLACE REFUSE %MOISTURE	GROUND REFUSE %MOISTURE	COD g/kg dry	TOC g/kg dry	TKN g/kg dry	CL g/kg dry
9A	46.8	4.02	1190	1110	6.93	1.18
9B	48.0	2.05	855	767	9.29	1.54
9C	44.2	1.39	800	754	8.95	1.69
10A	51.5	4.88	305	1260	15.1	3.58
10B	57.4	2.39	1730	1400	12.4	2.86
10C	50.5	2.41	1540	1090	8.58	2.46
11A	58.6	2.50	3290	2110	12.0	2.71
11B	57.4	2.48	2430	1800	16.0	3.08
11C	55.9	1.94	1800	1640	14.8	2.99
12A	54.3	4.34	1840	1270	14.9	2.44
12B	52.1	2.48	1210	1060	14.3	1.93
12C	57.3	3.25	2050	1440	14.7	3.62
13A	60.2	3.44	2250	1460	24.3	9.24
13B	56.5	3.48	1120	1340	23.9	5.57
13C	46.7	2.42	1200	1200	15.6	2.89
14A	57.4	10.5	2060	1790	21.6	8.66
14B	46.8	1.33	1140	941	8.50	4.28
14C	61.2	2.72	2080	1950	16.5	11.4
15A	56.3	1.64	1830	1020	15.0	1.49
15B	54.2	1.25	716	855	11.5	1.44
15C	56.0	1.46	1470	886	14.8	1.54
16A	53.5	5.67	1050	1020	14.0	1.95
16B	54.9	5.80	1400	1240	18.3	2.95
16C	48.1	24.5	3040	1640	26.1	4.64
17A	51.7	6.70	1100	1000	24.5	2.25
17B	51.0	11.9	1460	1200	33.9	2.30
17C	55.4	14.3	2270	1660	25.5	2.95
18A	53.5	3.37	1380	1140	14.7	2.60
18B	51.1	1.73	1790	1120	12.9	3.03
18C	61.7	2.06	2760	1870	23.7	4.50
19A	51.7	6.32	1810	1080	19.4	2.67
19B	44.7	0.85	992	597	14.2	1.40
19C	55.0	1.92	2340	1360	14.5	2.72

TABLE 46. METALS ANALYSIS OF INDUSTRIAL WASTE CELLS
Dry

SAMPLE	CR g/kg dry	CD g/kg dry	CU g/kg dry	FE g/kg dry	PB g/kg dry	NI g/kg dry	ZN g/kg dry
9A	0.533	<0.010	1.36	42.1	1.93	0.102	1.02
9B	0.786	<0.010	3.52	681	1.02	0.180	2.10
9C	0.426	<0.009	2.11	704	1.91	0.129	4.01
10A	0.185	<0.011	0.216	103	4.63	0.138	1.01
10B	0.109	<0.012	0.199	128	3.76	0.100	2.51
10C	0.066	<0.011	0.682	115	1.91	0.042	1.46
12A	2.611	0.068	1.16	46.3	7.08	0.157	9.25
12B	1.216	0.048	0.549	44.6	8.64	0.059	7.23
12C	1.036	0.066	0.729	69.5	1.85	0.111	5.62
13A	2.314	0.027	0.563	69.1	0.605	0.110	1.05
13B	1.948	<0.012	0.017	43.6	1.67	0.100	1.53
13C	0.495	0.020	0.179	42.3	1.55	0.059	1.42
14A	0.097	<0.016	0.162	64.0	1.21	0.093	15.0
14B	0.100	<0.010	0.374	61.9	0.694	0.039	4.52
14C	0.272	0.167	0.114	29.3	1.25	0.056	1.00
17A	0.572	<0.012	0.235	62.0	2.91	0.024	1.26
17B	0.207	0.029	0.248	24.5	1.32	0.054	1.03
17C	0.155	<0.016	0.201	29.7	1.48	0.033	2.36

TABLE 47. CHEMICAL ANALYSIS OF REFUSE (CELLS 1-8)
Wet

SAMPLE	IN PLACE REFUSE %MOISTURE	GROUND REFUSE %MOISTURE	COD g/kg wet	TOC g/kg wet	TKN g/kg wet	CL g/kg wet
1A	55.2	1.54	828	668	6.24	1.10
1B	45.2	1.65	425	450	4.47	0.780
1C	54.8	1.76	870	681	6.11	1.23
2A	55.5	6.58	981	664	7.68	1.18
2B	61.8	2.48	1050	745	8.75	0.589
2C	58.6	3.45	1020	720	9.08	1.03
3A	65.7	2.92	835	638	8.10	0.705
3B	52.9	1.82	767	594	6.14	0.757
3C	48.6	1.21	418	372	5.48	0.706
4A	56.5	2.61	622	510	7.29	0.921
4B	50.8	1.35	574	511	7.17	0.592
4C	56.3	2.07	685	593	8.02	0.650
5A	49.0	1.98	862	572	7.49	0.789
5B	60.0	2.34	995	639	5.60	0.649
5C	60.5	2.63	875	753	7.33	0.939
6A	52.5	2.63	865	621	5.85	0.930
6B	46.9	2.16	418	474	5.84	0.771
6C	53.3	2.33	899	752	4.17	1.03
7A	58.5	2.88	700	491	10.1	1.05
7B	49.6	2.13	613	431	7.29	0.666
7C	57.8	1.50	827	658	5.22	1.47
8A	51.0	1.81	670	535	5.18	0.776
8B	54.8	3.32	998	763	5.27	1.37
8C	57.5	5.05	1110	751	4.09	1.10

TABLE 48. CHEMICAL ANALYSIS OF REFUSE (CELLS 9-19)
Wet

SAMPLE	IN PLACE REFUSE %MOISTURE	GROUND REFUSE %MOISTURE	COD g/kg wet	TOC g/kg wet	TKN g/kg wet	CL g/kg wet
9A	46.8	4.02	585	547	3.41	0.578
9B	48.0	2.05	427	383	4.64	0.819
9C	44.2	1.39	435	410	4.87	0.919
10A	51.5	4.88	133	550	6.59	1.56
10B	57.4	2.39	696	561	4.99	1.15
10C	50.5	2.41	726	513	4.04	1.16
11A	58.6	2.50	1280	873	4.68	1.12
11B	57.4	2.48	974	815	6.42	1.40
11C	55.9	1.94	759	647	6.22	1.18
12A	54.3	4.34	761	525	6.15	1.01
12B	52.1	2.48	548	479	6.49	0.876
12C	57.3	3.25	809	569	5.79	1.43
13A	60.2	3.44	817	531	8.85	3.36
13B	56.5	3.48	450	537	9.55	2.23
13C	46.7	2.42	610	610	7.93	1.47
14A	57.4	10.5	662	576	6.94	2.78
14B	46.8	1.33	590	488	4.41	2.22
14C	61.2	2.72	750	703	5.94	4.11
15A	56.3	1.64	768	429	6.31	0.627
15B	54.2	1.25	319	381	5.14	0.642
15C	56.0	1.46	625	377	6.31	0.657
16A	53.5	5.67	427	418	5.72	0.797
16B	54.9	5.80	548	488	7.18	1.16
16C	48.1	24.5	832	450	7.15	1.27
17A	51.7	6.70	456	418	10.2	0.936
17B	51.0	11.9	541	445	12.6	0.854
17C	55.4	14.3	690	503	7.74	0.894
18A	53.5	3.37	594	492	6.36	1.12
18B	51.1	1.73	843	526	6.09	1.43
18C	61.7	2.06	1000	677	8.60	1.63
19A	51.7	6.32	759	452	8.16	1.12
19B	44.7	0.85	540	325	7.73	0.761
19C	55.0	1.92	1010	588	6.25	1.17

TABLE 49. METALS ANALYSIS OF INDUSTRIAL WASTE CELLS
Wet

SAMPLE	CR g/kg wet	CD g/kg wet	CU g/kg wet	FE g/kg wet	PB g/kg wet	NI g/kg wet	ZN g/kg wet
9A	0.262	<0.005	0.669	20.7	0.950	0.050	0.500
9B	0.393	<0.005	1.76	340	0.510	0.090	1.05
9C	0.232	<0.005	1.15	383	1.04	0.070	2.18
10A	0.081	<0.005	0.094	44.8	2.02	0.060	0.440
10B	0.044	<0.005	0.080	51.3	1.51	0.040	1.01
10C	0.031	<0.005	0.321	54.2	0.900	0.020	0.689
12A	1.08	0.028	0.478	18.0	2.93	0.065	3.60
12B	0.552	0.022	0.249	17.9	3.92	0.027	2.90
12C	0.409	0.026	0.288	29.3	0.730	0.044	2.37
13A	0.842	0.010	0.205	28.6	0.220	0.040	0.433
13B	0.780	<0.005	0.007	19.8	0.670	0.040	0.693
13C	0.252	0.010	0.091	16.7	0.790	0.030	0.560
14A	0.031	<0.005	0.052	23.3	0.390	0.030	5.47
14B	0.052	<0.005	0.194	24.8	0.360	0.020	1.81
14C	0.098	0.060	0.041	14.9	0.450	0.020	0.509
17A	0.238	<0.005	0.098	19.9	1.21	0.010	0.403
17B	0.077	0.013	0.092	12.7	0.490	0.020	0.534
17C	0.047	<0.005	0.061	10.7	0.450	0.010	0.850

Considerable amounts of chloride and nitrogen remained in the waste materials in all cells. Nutrients should not have been limiting in any case.

Considerable metals were present, as one would expect in refuse. Metals were only analyzed in the co-disposal cells. Iron was highest in the co-disposal cells. The order in decreasing concentrations was iron, zinc, lead, chromium, copper, nickel, and cadmium. Mean values on a dry weight basis were as follows for the co-disposal cells: iron, 131 g/kg; zinc, 3.52 g/kg; lead, 2.52 g/kg; chromium, 0.729 g/kg; copper, 0.701 g/kg; nickel, 0.088 g/kg; and cadmium, 0.024 g/kg. These values were not unexpected from the particular industrial sludges involved. For example, the highest test cell concentration for cadmium was in test cell #12, which had plating wastes.

BOTTOM GRAVEL ANALYSIS

Bottom gravel condition was excellent in all cells. There was some intermingling and sticking of waste materials to the gravel at the waste-gravel interface, but the gravel was basically like new. There was no cementation of the gravel. Some thin layers of black residue were on the gravel, but the residue could be wiped off readily. Analysis of the void space (Table 50) of the cells indicated plenty of space (around 50%) available for leachate storage. Analysis of the residue for sulfide and COD was conducted (Table 51). There were sulfides present in the residue from most lysimeters and residual oxidizable organics in all. COD's varied from 5.7 mg/g to 127.2 mg/g of the black residue. This indicated a wide range of materials that were chemically oxidizable. Gravel would have continued to function indefinitely under these conditions.

TABLE 50. BOTTOM GRAVEL PERCENT VOIDS

TEST CELL	PERCENT VOIDS
1	44
2	44
3	60
4	48
5	45
6	50
7	48
8	44
9	44
10	48
11	50
12	48
13	48
14	46
15	52
16	No Samples
17	48
18	68
19	No Samples

TABLE 51. BOTTOM GRAVEL CONDITION -- COD AND SULFIDE LEVELS IN RESIDUE ON GRAVEL

TEST CELL	SULFIDE@ mg/g RESIDUE	COD mg/g RESIDUE
1	0.09	43.7
2	0.05	36.6
3	*	5.66
4	0.08	33.2
5	0.11	20.4
6	*	6.93
7	*	7.13
8	0.05	27.4
9	0.04	41.6
10	††	55.3
11	††	27.1
12	0.13	7.45
13	††	127
14	††	21.0
15	0.01	54.9
16	No Sample	No Sample
17	0.03	59.4
18	*	24.6
19	No Sample	No Sample

@ Sulfide results are based on semi-quantitative analysis, subject to considerable error.

* No apparent sulfide in residue

†† Trace amount of sulfide present, but too low to quantify

LEACHATE ANALYSIS

Data from the last month of continuous monitoring of the test cells (April 1983) are presented in Tables 52, 54 and 56. Data from this termination study (June 1984) are presented in Tables 53, 55, and 57. Many of the parameters in these two sampling periods were not significantly different (chlorides, TKN, alkalinity, total phosphate). However, there were some changes noted.

In comparing the data, it should be kept in mind that the April 1983 data represented leachate that was generated as a result of routine water addition and monthly leachate collection from each cell. From May 1983 through December 1983, moisture addition continued and leachate was drained from the cells, but the leachate was only analyzed for a limited number of parameters during this time. There was no moisture added to the cells, nor was any leachate drained from the cells from January 1984 until June 1984, when the termination study leachate was collected. Leachate volume was not measured in the June 1984 collection, so it is not possible to interpret the effect of dilution on the various parameters.

pH

The pH of the leachate was essentially the same for all test cells except for test cells 14, 16, 17, 18, and 19. The pH of test cell 14 was 0.3 pH units lower than in April 1983; test cell 16 was 0.5 pH units lower; test cell 17 was 0.5 units lower; test cell 18 was 0.55 units lower; and test cell 19 was 0.5 units lower. These lower pH values are indicative of a trend toward stronger acid conditions. The leachate had been stored away from the alkalinity of most of the refuse, so acid conditions predominated.

Conductivity

Conductivity generally decreased in all cells except test cells 15 and 17. Differences noted between the two sample dates were not significant for this complex matrix. The values ranged here from a low of 1320 µmhos/cm for test cell 17 in April to a high of 7020 µmhos/cm in test cell 13, so the values were not too different for the two sample periods.

Solids

The leachate total solids concentrations increased in 68 percent of the cells from the April 1983 sampling to the June 1984 sampling. April 1983 concentrations ranged from a low of 1320 mg/L in cell 17 to a high of 8790 mg/L in test cell 1. June 1984 leachate total solids concentrations were of similar magnitude, ranging from 1110 mg/L in cell 15 to 10,200 mg/L in cell 1. Volatile solids concentrations mirrored the total solids concentrations, increasing and decreasing from April 1983 to June 1984, as did the total solids concentrations in each cell. Volatile solids concentrations in April 1983 ranged from 305 mg/L in cell 4 to 4800 mg/L in cell 1. June 1984 leachate volatile solids concentrations ranged from 395 mg/L in cell 15 to 5950 mg/L in cell 1. Overall, the solids concentrations are not too different for the two sampling periods.

TABLE 52. FINAL CONTINUOUS MONITORING LEACHATE (CHEMICAL)
April 1983

CELL #	TOC (mg/l)	COD (mg/l)	ALK (mg/l)	TKN (mg/l)	PO4-P (mg/l)	CL (mg/l)
1	5200	16900	4780	342	16.1	259
2	3080	10600	2430	170	19.4	116
3	175	640	1660	28.7	1.93	71.5
4	71.0	251	1300	18.3	1.44	57.4
5	2570	8080	2240	161	23.3	98.9
6	3500	11000	3180	220	19.5	171
7	3180	9790	3350	156	14.0	128
8	3180	9960	2940	218	20.8	146
9	371	1420	1710	90.2	1.89	112
10	1840	5720	3360	24.6	0.13	116
11	2960	9910	2290	150	30.3	126
12	1180	4150	2470	65.4	2.63	94.6
13	4040	18000	5020	210	1.57	376
14	245	893	2170	48.0	3.15	1320
15	13.5	60.6	611	21.6	0.50	18.4
16	104	309	1340	103	1.40	154
17	110	297	964	58.8	1.80	74.6
18	94.8	307	1090	69.6	0.70	164
19	97.0	288	1080	77.9	1.04	144

TABLE 53. TERMINATION STUDY LEACHATE (CHEMICAL)
June 1984

CELL #	TOC (mg/l)	COD (mg/l)	ALK (mg/l)	TKN (mg/l)	PO4-P (mg/l)	CL (mg/l)
1	5840	17200	5950	431	14.6	327
2	3080	10600	2900	194	19.1	115
3	115	395	1820	26.8	1.00	56.6
4	57.1	200	1340	25.0	1.41	30.9
5	1650	5520	2000	78.4	17.4	48.0
6	3360	10700	3670	168	16.8	185
7	1105	3100	3360	120	1.51	130
8	2970	9740	3020	204	20.7	132
9	182	568	2700	108	1.87	110
10	123	392	1630	19.6	0.45	113
11	2910	9900	2860	157	27.1	99.0
12	245	635	2090	50.7	2.76	125
13	4910	15000	5870	221	2.66	453
14	247	737	2100	43.4	2.03	1520
15	7.21	59.4	735	30.8	0.48	22.6
16	108	415	1710	161	0.54	183
17	120	291	1330	107	1.14	82.3
18	110	305	1240	81.9	0.54	193
19	108	293	1320	101	0.41	152

TABLE 54. FINAL CONTINUOUS MONITORING LEACHATE (PHYSICAL)
April 1983

CELL #	pH	ORP (mV)	COND (umhos/cm)	TS (mg/l)	TVS (mg/l)
1	5.57	582	7020	8790	4800
2	5.55	552	3820	4940	2820
3	6.40	302	2890	2430	560
4	6.37	172	2320	1700	305
5	5.60	207	3580	4220	2340
6	5.67	172	4840	6050	3310
7	5.80	157	4870	5940	2960
8	5.80	167	4440	5420	3100
9	6.68	92	3100	2780	970
10	6.53	102	4620	5120	1920
11	5.70	162	3560	4800	2810
12	6.45	112	3660	4040	1960
13	5.80	187	6910	7880	3540
14	6.76	112	6902	7280	1740
15	6.38	142	1210	1270	325
16	6.65	102	2690	1880	480
17	6.40	107	1840	1320	370
18	6.55	110	2320	1730	485
19	6.50	102	2260	1650	400

TABLE 55. TERMINATION STUDY LEACHATE (PHYSICAL)
June 1984

CELL #	pH	ORP (mV)	COND (umhos/cm)	TS (mg/l)	TVS (mg/l)
1	5.60	135	4500	10200	5950
2	5.62	40	2620	5530	3330
3	6.35	-10	1700	2560	980
4	6.35	-40	1460	2170	880
5	5.50	-2.0	1950	3610	2040
6	5.68	-5.0	3300	6480	3700
7	6.70	-85	3000	4940	2130
8	5.85	-22	2880	5780	3470
9	6.60	-15	2320	2910	1260
10	6.48	-10	1880	2550	890
11	5.75	0	2680	5260	3100
12	6.40	-10	2000	3270	1400
13	5.75	0	4850	9310	4750
14	6.48	-10	3800	4880	1330
15	6.35	-10	1380	1110	395
16	6.10	-50	2480	2320	940
17	5.95	-90	2120	1740	680
18	6.00	-70	2100	2030	885
19	6.00	-75	2020	1920	770

TABLE 56. FINAL CONTINUOUS MONITORING LEACHATE (METALS)
April 1983

CELL#	CR mg/l	CD mg/l	CU mg/l	FE mg/l	NI mg/l	PB mg/l	ZN mg/l
1	0.038	0.016	0.032	678	0.20	0.16	0.382
2	< 0.025	0.011	< 0.025	340	0.12	0.10	0.583
3	< 0.025	0.012	0.025	438	0.06	0.08	0.096
4	< 0.025	< 0.010	< 0.025	281	0.08	0.06	0.040
5	< 0.025	< 0.010	< 0.025	266	0.10	0.09	0.079
6	< 0.025	0.014	< 0.025	382	0.13	0.12	0.030
7	0.036	0.015	< 0.025	565	0.23	0.12	0.077
8	0.029	< 0.010	< 0.025	189	0.13	0.10	0.066
9	< 0.025	< 0.010	< 0.025	336	0.06	0.09	0.081
10	0.035	0.013	0.026	1020	0.09	0.12	0.406
11	< 0.025	< 0.010	< 0.025	346	0.11	0.09	1.80
12	0.062	0.012	0.062	480	0.63	0.10	0.676
13	< 0.025	0.015	0.031	979	0.24	0.16	1.57
14	0.117	< 0.010	0.036	219	0.12	0.12	0.227
15	< 0.025	< 0.010	< 0.025	154	0.04	< 0.05	0.066
16	0.032	< 0.010	< 0.025	82.4	0.05	0.06	0.081
17	0.027	< 0.010	0.027	99.2	0.06	< 0.05	0.061
18	0.031	< 0.010	0.026	78.7	0.04	0.06	0.034
19	0.051	< 0.010	0.032	76.7	0.06	0.06	0.091

Chemical Oxygen Demand (COD)

Chemical oxygen demand did not change appreciably for the two sampling periods. Seven of the nineteeen cells had virtually the same values. Two cells were a little higher, but not appreciably so: test cells 1 and 16. The rest were slightly lower: some ten out of nineteen, or 53%. This suggested some continual decomposition, but the absolute values were not too different except for test cells 10 and 12, where there were significant decreases in the COD.

Total Organic Carbon (TOC)

Total organic carbon values decreased slightly in eleven of the nineteen cells in the June 1984 leachate. The values paralleled the values predicted by the COD measurement. Only test cells 1 and 13 increased in value. Test cells 2, 14, 16, 17, 18, and 19 were the same. The others had values which showed a decrease. This suggested continued decomposition in the majority of the test cells after this time period from April 1983 to the completion of the study.

TABLE 57. TERMINATION STUDY LEACHATE (METALS)
June 1984

CELL#	CR mg/l	CD mg/l	CU mg/l	FE mg/l	NI mg/l	PB mg/l	ZN mg/l
1	0.036	0.016	<.025	1620	0.164	0.15	0.154
2	<.025	0.009	<.025	855	0.109	0.08	0.098
3	<.025	0.006	<.025	667	0.099	0.05	0.152
4	<.025	0.005	<.025	535	0.114	0.06	0.072
5	<.025	0.006	<.025	603	0.083	0.07	0.071
6	0.027	0.012	<.025	1050	0.129	0.12	0.071
7	0.025	0.011	<.025	953	0.257	0.13	0.140
8	<.025	0.011	<.025	503	0.199	0.10	0.054
9	<.025	0.008	<.025	169	0.060	0.10	0.082
10	<.025	0.010	<.025	285	0.062	0.10	0.166
11	<.025	0.011	<.025	763	0.089	0.11	0.413
12	0.033	0.009	<.025	429	0.327	0.11	0.252
13	0.031	0.020	0.028	2280	0.208	0.19	0.384
14	<.025	0.006	<.025	411	0.142	0.11	0.123
15	<.025	<.005	<.025	392	0.111	<.05	0.046
16	<.025	0.005	<.025	132	<.040	0.05	0.167
17	<.025	<.005	<.025	206	<.040	<.05	0.720
18	<.025	<.005	<.025	98.7	<.040	<.05	0.045
19	<.025	0.006	<.025	140	0.127	0.05	<.025

Metals

Concentrations of cadmium, chromium, copper, lead, and nickel were essentially the same in the April 1983 leachate as in the June 1984 leachate. Most of these metals concentrations were below or very near the detection limit for each given metal. This would tend to suggest that the concentrations were very low throughout the ten-year project or that most of the exposed sources of these metals had already been leached from the refuse.

Iron concentrations were several orders of magnitude higher than any of the other metals in the April 1983 leachate and increased significantly in the June 1984 leachate for all cells except for test cells 10 and 12. Test cell 12 decreased from 480 mg/L in April 1983 to 429 mg/L in June 1984. Test cell 10 decreased from 1020 mg/L in April 1983 to 285 mg/L. The decrease in the iron concentration for these cells was unexpected. The organic acids present would tend to form complexes with the iron, but over time, given the acidic pH of the leachate, the iron would tend to go into solution.

Zinc concentrations decreased in concentration in about 50 percent of the cells and increased in the other 50 percent from the April 1983 leachate sampling to the June 1984 sampling. Given the amount of zinc in the refuse, the differences seen were not too large.

It is difficult to draw many conclusions about the possible changes in the leachate over time without comparing the differences seen from April 1983 to June 1984 to the differences seen in the leachate from month to month during the continuous monitoring portion of the ten-year study. Although changes have occurred, these changes can not be directly attributed to the lack of moisture addition and leachate collection immediately prior to the June 1984 leachate sampling.

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APPENDIX A. LOG OF LYSIMETER FINDINGS

LOG OF LYSIMETER FINDINGS: TEST CELL 1
Physical Conditions

CELL CONTENTS: Municipal Refuse

MOISTURE ADDITION: 200 mm/yr

PERMEABILITY: 1.26×10^{-2}

SPECIFIC YIELD: Short term: 2.69 $ft^3/hr/yd^3$
Total: 0.078 $ft^3/hr/yd^3$

SEALS AND COAL TAR EPOXY:

Seal around lid: Good condition, watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Slight bubbling on sides, areas of peeling on side
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, gravel like original condition when cleaned

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening,contents appear like a black tar-like mass with some recognizable items (e.g. cans), many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Bottles - Unbroken, some with labels intact and legible
Small plastic items - No apparent degradation, probably in original discarded condition (e.g. hair curler, toothbrush, toys)
Stainless steel utensils - No apparent degradation
Silverplate utensils - Silver oxide coating on surface
Harmonica - Small amount of rust on metal plated sides

Steel tools - Very rusted
Photograph - Black & white photo, very good condition
Records - Labels like original condition, vinyl in very good condition
Playing cards - Some attack on dyes
Readily Identifiable Organic Products - pickles in jar, corn on the cob, oranges, grapefruit, green grass, green leaves, bagged horse manure
Cloth - Synthetic and protected natural fibers strong, unprotected natural fibers weak, colors vivid
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 1
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 17 inches	Sample B 61 inches	Sample C 77 inches
Total Coliforms	7.33×10^5	1.46×10^6	4.86×10^6
Fecal Coliforms	1.33×10^2	$< 5.50\times10^1$	$< 6.00\times10^1$
Fecal *Streptococci*	8.00×10^6	6.49×10^6	1.00×10^8
C. perfringens (SF)	NA	NA	NA
C. perfringens (TSC)	NA	NA	NA
Total Plate Count (aer)	NA	NA	NA
Total Plate Count (an)	NA	NA	NA
Gram Negative Rods	6.97×10^{10}	7.81×10^{10}	2.11×10^{11}
Fungi	NA	NA	NA

* Diaper NA: Not analyzed

LOG OF LYSIMETER FINDINGS: TEST CELL 2
Physical Conditions

CELL CONTENTS: Municipal Refuse

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: 1.14×10^{-2}

SPECIFIC YIELD: Short term: 2.81 $ft^3/hr/yd^3$
Total: 0.117 $ft^3/hr/yd^3$

SEALS AND COAL TAR EPOXY:

Seal around lid: Good condition, watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Slight bubbling on sides, areas of peeling on side
Coal Tar Epoxy: Excellent condition, some bubbling in places, most of cell wall still protected

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening, contents appear like a black tar-like mass with some recognizable items (e.g. cans), many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Newspaper - Damp, writing clearly legible
Campaign Pamphlets - Damp, writing and color very clear
Tin Can - Campbells mushroom soup, paper intact, red color slightly faded, no apparent degradation of tin can
Small plastic items - No apparent degradation
Sea Shell - Color faded
Magazines - Vivid color still apparent
Light Bulb - Intact "Eye Saving 75 Watt" clearly legible
Jewelry - Discolored
Magnet - Rusty, red and yellow paint still discernible
Readily Identifiable Organic Products - Carrots (still orange), bread, cheese, evergreen trimmings
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - with fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 3
Physical Conditions

CELL CONTENTS: Municipal Refuse

MOISTURE ADDITION: 600 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: Good condition, not watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Slight bubbling on sides, areas of peeling on side
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, gravel like original condition when cleaned

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening, contents appear like a black tar-like mass with some recognizable items, cans basically gone,fairly advanced stage of decomposition, many paper and plastic bags with refuse intact, some readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Leather sandal - Discolored - black and green, tooled design still clear
Wooden Block - Very dark, some sides still legible with letters of alphabet
Newspaper - Very legible
Readily Identifiable Organic Products - Green grass,green leaves, corn cob, seeds, bones
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 3
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 16 inches	Sample B* 46 inches	Sample C 76 inches
Total Coliforms	1.00×10^7	9.46×10^4	4.59×10^6
Fecal Coliforms	6.57×10^5	$< 5.00 \times 10^1$	$< 5.00 \times 10^1$
Fecal Streptococci	1.40×10^4	3.51×10^4	2.97×10^4
C. perfringens (SF)	1.54×10^7	9.46×10^7	1.89×10^7
C. perfringens (TSC)	2.00×10^5	1.00×10^6	8.11×10^4
Total Plate Count (aer)	7.71×10^9	4.32×10^{10}	4.59×10^{10}
Total Plate Count (an)	8.57×10^{10}	1.30×10^{11}	4.59×10^{11}
Gram Negative Rods	9.43×10^8	9.19×10^7	8.92×10^7
Fungi	1.06×10^6	8.11×10^4	2.30×10^5

* Diaper NA: Not analyzed

METHANE PRODUCTION

Inoculum Sample Level	Inoculum Wet Weight (grams)	Gas Composition of Culture Vials $\%CO_2$	$\%O_2$	$\%N_2$	$\%CH_4$
3A	5.0	lids blew off vials			
	0.5	48.07	0.0	5.28	46.65
	0.05	43.89	0.0	6.34	49.77
	0.005	53.87	0.0	3.51	42.62
	0.0	80.93	2.86	16.21	0.0
3B	5.0	62.38	0.15	5.75	31.72
Diaper	0.5	34.46	0.41	28.54	36.59
	0.05	35.16	0.58	29.32	34.94
	0.005	39.34	0.45	29.91	30.30
	0.0	61.40	0.63	37.97	0.00
3C	5.0	62.27	0.31	13.96	23.46
	0.5	48.32	0.74	17.59	33.35
	0.05	39.94	0.38	11.17	48.51
	0.005	49.59	0.25	12.66	37.50
	0.0	80.67	0.37	18.96	0.0

LOG OF LYSIMETER FINDINGS: TEST CELL 3
Microbiology

MICROORGANISMS IDENTIFIED

Microbial Type	Microbial Identification	Sample Level (Inches into Refuse)	Concentration (CFU/100g wet)
Clostridium	*C. bifermentans*	A (16")	1×10^4
	C. difficile	A	1×10^4
Fungi	*Aspergillus fumigatus*	A (16")	1×10^4
	Cephalosporium sp.	A	4×10^6
	Geotrichum sp.	A	1×10^7
	Monosporium sp.	A	4×10^5
	Paecilomyces sp.	A	4×10^5
	Penicillium sp.	A	1×10^5
	Scopulariopsis sp.	A	1×10^7
	Syncephalastrum sp.	A	4×10^5
	Trichophyton sp.	A	3×10^6
	Aureobasidium sp.	B (46")*	6×10^6
	Cephalosporium sp.	B	1×10^5
	Cladosporium sp.	B	1×10^7
	Epicoccum sp.	B	1×10^4
	Aspergillus sp.	C (76")	1×10^6
	Cladosporium sp.	C	1×10^6
Gram Negative Rods	*Acinetobacter calcoaceticus* var. *anitratus*	A (16")	1×10^9
	Acinetobacter calcoaceticus var. *lwoffi*	A	9×10^9
	Acinetobacter sp.	A	6×10^7
	Alcaligenes sp.	A	1×10^7
	Citrobacter freundii	A	3×10^7
	Enterobacter cloacae	A	7×10^7
	Enterobacter agglomerans	B (46")*	1×10^8
	Pseudomonas sp.	B	4×10^8
	Pseudomonas agglomerans	B	1×10^7

* Diaper Sample

LOG OF LYSIMETER FINDINGS: TEST CELL 4
Physical Conditions

CELL CONTENTS: Municipal Refuse

MOISTURE ADDITION: 800 mm/yr

PERMEABILITY: 1.00×10^{-2}

SPECIFIC YIELD: Short term: 1.84 $ft^3/hr/yd^3$
Total: 0.027 $ft^3/hr/yd^3$

SEALS AND COAL TAR EPOXY:

Seal around lid: Good condition, watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Slight bubbling on sides, no apparent peeling on side
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening,very wet and dark, contents appear like a black tar-like mass with a few recognizable items, no cans visible, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Leather shoes - Very discolored, obvious degradation
Metal cooking utensils - Rusted and discolored, wooden handle intact
Wooden blocks - Some discoloration, letter and colors still clearly visible
Small lock in original package - Plastic covering over cardboard backing still holding lock in place. Printing and color still very clear.
License plate - Partially legible, color gone
Candle - Intact, probably in original discarded condition
Readily Identifiable Organic Products - Orange rind, grass clippings, bread cheese
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 5
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Sewage Sludge

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: Good condition, watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Slight bubbling on sides, no apparent peeling on side
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: Thin sludge layer approximately 1 to 1 1/2 inch thick, layer not continuous over cell

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening,very wet, sludge layers mixed with refuse, looks like humus, contents appear like a black tar-like mass with some recognizable items, no cans visible, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Wooden measuring tape - Grayish cast, numbers and marks clearly legible
Metal measuring tape - No apparent degradation
License plates - clearly legible, background color faded
Leather shoes - Discolored, visible degradation, good shape
Canvas shoe - Intact, fiber strong
Books - Good condition, photographs and colors still clear
1953 Silver half dollar - No apparent attack
Readily Identifiable Organic Products - Carrots, steaks, mett, corn on the cob, hot dogs, cheese, bologna sandwich, green grass clippings
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 6
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Sewage Sludge

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: Good condition, watertight, not gas tight
Seal around water infiltration line: Cracked
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Slight bubbling on sides, no apparent peeling on sides
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: Strong odor upon opening, contents appear like a black tar-like mass with a few recognizable items, no cans visible, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Books and magazines - Clearly legible, slightly discolored
Film negatives - Images still clear
Perfume bottles - Perfume fragrance still evident
License plate - Still clearly legible, color clear, slightly rusty
Readily Identifiable Organic Products - Green grass, green trimmings, grapefruit, green beans, cheese, corn on the cob, sweet potatoes, jar with mustard in it
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 7
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Sewage Sludge

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: Good condition, watertight, not gas tight
Seal around water infiltration line: Cracked
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Very little bubbling on sides, some areas of peeling on side
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: Strong odor upon opening, some small amounts of sludge on other items, decomposition appeared fairly well advanced, contents appear like a black tar-like mass with a few recognizable items, no cans visible, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Penny - 1974, coated with black sulfide residue, some areas where copper has obviously been attacked, increased 0.53g in weight from new penny
Pepsi can - Aluminum can intact, Pepsi still in can, colors and writing still clear
Copper pipe - Good condition, coated with black sulfide residue
Readily Identifiable Organic Products - Cabbage, cheese, chicken, ribs, green grass, oranges, leaves, hot dogs, squirrel tail, turnips
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 7
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 30 inches	Sample B 60 inches	Sample C 92 inches
Total Coliforms	$3.25x10^{5}$	$4.87x10^{3}$	$4.64x10^{2}$
Fecal Coliforms	$6.00x10^{4}$	$< 5.50x10^{1}$	$< 7.00x10^{1}$
Fecal Streptococci	$1.68x10^{3}$	$4.10x10^{6}$	$4.64x10^{3}$
C. perfringens (SF)	$1.98x10^{6}$	$7.18x10^{6}$	$8.57x10^{6}$
C. perfringens (TSC)	$1.52x10^{7}$	$1.92x10^{7}$	$7.14x10^{5}$
Total Plate Count (aer)	$1.85x10^{11}$	$1.05x10^{9}$	$4.28x10^{12}$
Total Plate Count (an)	$1.80x10^{11}$	$6.41x10^{8}$	$8.21x10^{9}$
Gram Negative Rods	$4.75x10^{10}$	$1.59x10^{9}$	$1.07x10^{5}$
Fungi	$9.00x10^{7}$	$1.00x10^{6}$	$4.64x10^{5}$

* Diaper NA: Not analyzed

METHANE PRODUCTION

Inoculum		Gas Composition of Culture Vials			
Sample Level	Wet Weight (grams)	$\%CO_2$	$\%O_2$	$\%N_2$	$\%CH_4$
7A	5.0	38.49	0.30	11.74	49.47
	0.5	41.50	0.15	6.44	51.91
	0.05	70.66	0.69	19.78	8.87
	0.005	72.74	0.43	24.28	2.55
	0.0	87.95	1.20	10.85	0.0
7B	5.0	23.10	1.56	73.90	1.44
	0.5	81.36	0.37	18.27	0.0
	0.05	74.46	0.35	19.07	6.12
	0.005	77.44	0.26	15.66	6.64
	0.0	83.47	0.44	16.09	0.00
7C	5.0	52.35	0.21	8.05	39.39
	0.5	80.94	1.16	14.89	3.01
	0.05	83.62	0.79	13.42	2.17
	0.005	79.30	0.97	19.73	0.0
	0.0	79.74	0.36	19.90	0.0

LOG OF LYSIMETER FINDINGS: TEST CELL 7
Microbiology

MICROORGANISMS IDENTIFIED

Microbial Type	Microbial Identification	Sample Level (Inches into Refuse)	Concentration (CFU/100g wet)
Clostridium	C. histolyticum	A (30")	1×10^4
	C. botulinum	B (60")	2×10^7
	C. botulinum	C (92")	1×10^4
Fungi	Cladosporium sp.	A (30")	5×10^8
	Madurella sp.	A	1×10^5
	Monosporium apiospermum	A	5×10^5
	Monosporium sp.	A	1×10^8
	Penicillium sp.	A	1×10^7
	Scopulariopsis sp.	A	5×10^5
	Trichoderma sp.	A	5×10^8
	Trichophyton sp.	A	1×10^9
	Yeast	A	2×10^8
	Aspergillus fumigatus	B (60")	6×10^5
	Aspergillus niger	B	1×10^5
	Cladosporium sp.	B	1×10^6
	Phoma sp.	B	5×10^7
	Pencillium sp.	B	2×10^5
	Sepedonium sp.	B	1×10^5
	Trichophyton sp.	B	6×10^5
	Aureobasidium sp.	C (92")	1×10^6
	Cladosporium sp.	C	2×10^6
	Gliocladium sp.	C	1×10^6
	Madurella mycetomi	C	1×10^4
	Monosporium sp.	C	1×10^6
	Penicillium sp.	C	7×10^5
	Yeast	C	1×10^4
Gram Negative Rods	Acinetobacter calcoaceticus var. lwoffi	A (30")	9×10^9
	Hafnia alvei	A	2×10^6
	Klebsiella pneumoniae	A	5×10^4
	Pseudomonas sp.	A	3×10^7
	Serratia fonticola	A	1×10^7
	Tatumella ptyseos	A	1×10^5
	Citrobacter freundii	B (60")	1×10^6
	Serratia sp.	C (92")	1×10^4
	Serratia liquefaciens	C	1×10^4

LOG OF LYSIMETER FINDINGS: TEST CELL 8
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Calcium Carbonate Sludge

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: Good condition, watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Very little bubbling on sides, no apparent peeling on side
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering, clumps of calcium carbonate

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening, contents appear drier than other cells, clear clumps of calcium carbonate, remaining contents appear like a black tar-like mass with a few recognizable items, no cans visible, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Canvas shoes - Some degradation obvious
Wooden clothes pins - Very dark, many of them black
Baseball cards - Good condition, color photos clear
Books and Newspaper - Wet, print legible, clear degradation around edges
Key - Intact, coated with residue
Readily Identifiable Organic Products - Pretzels, lunch meat, green grass, kitchen scraps, beets, potato peels, cheese, corn on the cob, broccoli, wigs, coconut
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 9
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Petroleum Sludge

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: (Plywood lid)seal was open, not watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Poor condition, considerable breakdown of fibers, still watertight
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: Very strong odor upon opening, sludge covering everything, contents appear like a black tar-like mass with a few recognizable items, where sludge protects refuse, refuse is very dry, normal decomposition where refuse is exposed to water, clear channeling of water around sludge, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Small plastic items - No apparent degradation
Pennies - 1964, 1940, 1974 with black sulfide residue coating, some greenish residue
1973, 1967 with some black sulfide coating , very shiny areas evidence of attack on copper
Readily Identifiable Organic Products - Bread, meat, vegetables, double mint chewing gum, chocolate candy, ham
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 9
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 22 inches	Sample B 46 inches	Sample C 76 inches
Total Coliforms	1.26×10^{5}	7.00×10^{4}	1.23×10^{4}
Fecal Coliforms	1.38×10^{4}	1.40×10^{2}	$< 5.00 \times 10^{1}$
Fecal Streptococci	8.97×10^{4}	2.80×10^{3}	1.11×10^{3}
C. perfringens (SF)	5.64×10^{6}	1.40×10^{7}	2.09×10^{7}
C. perfringens (TSC)	4.36×10^{5}	6.20×10^{7}	2.23×10^{7}
Total Plate Count (aer)	5.38×10^{10}	9.20×10^{8}	3.64×10^{10}
Total Plate Count (an)	2.82×10^{8}	5.80×10^{7}	7.73×10^{8}
Gram Negative Rods	1.05×10^{10}	5.40×10^{8}	3.86×10^{7}
Fungi	1.36×10^{8}	1.08×10^{8}	5.45×10^{7}

* Diaper NA: Not analyzed

METHANE PRODUCTION

Inoculum		Gas Composition of Culture Vials			
Sample Level	Wet Weight (grams)	$\%CO_2$	$\%O_2$	$\%N_2$	$\%CH_4$
9A	5.0	lids blew off vials			
	0.5	lids blew off vials			
	0.05	49.08	1.03	2.51	47.38
	0.005	55.66	0.0	3.59	40.75
	0.0	71.39	0.75	27.86	0.0
9B	5.0	lids blew off vials			
	0.5	49.84	0.68	2.39	47.09
	0.05	42.76	0.43	3.31	53.50
	0.005	83.92	2.43	13.65	0.0
	0.0	90.09	1.44	8.47	0.0
9C	5.0	34.15	0.0	1.54	64.31
	0.5	46.25	0.0	2.93	50.82
	0.05	45.05	0.0	2.67	52.28
	0.005	78.92	0.95	7.30	12.83
	0.0	91.79	1.08	7.13	0.0

LOG OF LYSIMETER FINDINGS: TEST CELL 9
Microbiology

MICROORGANISMS IDENTIFIED

Microbial Type	Microbial Identification	Sample Level (Inches into Refuse)	Concentration (CFU/100g wet)
Clostridium	*C. perfringens*	B (46")	5x10^6
	C. ramosum	B	1x10^6
	C. paraperfringens	C (79")	1x10^5
	C. perfringens	C	1x10^6
	C. sordellii	C	1x10^5
Fungi	*Aspergillus* sp.	A ((22")	1x10^4
	Aspergillus nidulans	A	4x10^6
	Cephalosporium sp.	A	6x10^5
	Monosporium apiospermum	A	1x10^6
	Nigrospora sp.	A	1x10^4
	Penicillium sp.	A	2x10^4
	Cephalosporium sp.	B (46")	1x10^7
	Cladosporium sp.	B	2x10^6
	Monosporium apiospermum	B	3x10^6
	Monosporium apiospermum	C (76")	2x10^6
	Penicillium sp.	C	9x10^6
	Yeast	C	7x10^6
Gram Negative Rods	*Aeromonas hydrophila*	C (76")	6x10^6
	Serratia fonticola	C	5x10^7

LOG OF LYSIMETER FINDINGS: TEST CELL 10
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Battery Production Waste

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: (Plywood lid) seal was open, not watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Fair condition, surface rough, gravel embedded in fiberglass, bubbling, no apparent peeling, watertight
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening, black material covering everything, black material turned red on contact with air and light,far along in decomposition, some recognizable items, paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Toy stuffed bear - Poor condition, obvious degradation
Leather shoes - Very black, obvious degradation
Small plastic items - No apparent degradation
License plate - Background color faded, writing clear, some rust other plated very rusty not entirely legible
Newspaper and books - Discolored, redish cast, obvious degradation
Baseball cards and Valentines - Colors fading, most still legible
Readily Identifiable Organic Products - Chocolate chips, bacon, bologna,bread,apple peels, potato peels, carrots
Cloth - Synthetic and protected natural fibers strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 10
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 44 inches	Sample B 64 inches	Sample C 80 inches
Total Coliforms	$< 5.00\times10^1$	1.00×10^3	4.86×10^3
Fecal Coliforms	$< 5.00\times10^1$	$< 6.00\times10^1$	5.40×10^2
Fecal Streptococci	1.28×10^2	1.51×10^3	5.40×10^2
C. perfringens (SF)	8.97×10^5	7.27×10^6	2.97×10^7
C. perfringens (TSC)	3.59×10^5	5.45×10^6	3.25×10^7
Total Plate Count (aer)	7.18×10^6	1.12×10^8	5.40×10^{10}
Total Plate Count (an)	1.31×10^6	1.24×10^8	1.92×10^8
Gram Negative Rods	$< 2.50\times10^4$	6.67×10^{10}	1.05×10^8
Fungi	1.15×10^7	1.06×10^7	3.78×10^7

* Diaper NA: Not analyzed

METHANE PRODUCTION

Inoculum Sample Level	Wet Weight (grams)	Gas Composition of Culture Vials $\%CO_2$	$\%O_2$	$\%N_2$	$\%CH_4$
10A	5.0	53.85	0.25	13.20	32.70
	0.5	70.65	0.38	25.56	3.41
	0.05	76.49	0.34	23.17	0.0
	0.005	78.67	0.31	21.02	0.0
	0.0	81.08	0.34	18.58	0.0
10B	5.0	50.75	0.0	7.82	41.43
	0.5	43.24	0.22	13.10	43.44
	0.05	60.25	0.33	17.95	21.47
	0.005	77.86	0.46	21.68	0.0
	0.0	67.15	0.0	32.85	0.0
10C	5.0	51.36	0.41	17.04	31.19
	0.5	47.09	0.29	17.78	34.84
	0.05	74.87	0.59	20.12	4.42
	0.005	42.87	0.29	15.36	41.48
	0.0	69.62	0.54	29.84	0.0

LOG OF LYSIMETER FINDINGS: TEST CELL 10
Microbiology

MICROORGANISMS IDENTIFIED

Microbial Type	Microbial Identification	Sample Level (Inches into Refuse)	Concentration (CFU/100g wet)
Fungi	*Cephalosporium* sp.	A (44")	$1x10^6$
	Sepedonium sp.	A	$1x10^6$
	Allescheria boydii	B (64")	$2x10^4$
	Alternaria sp.	B	$1x10^5$
	Rhodotorula sp.	B	$1x10^4$
	Sepedonium sp.	B	$4x10^6$
	Allescheria boydii	C (80")	$3x10^5$
	Penicillium sp.	C	$1x10^6$
	Sepedonium sp.	C	$1x10^7$
Gram Negative Rods	*Pseudomonas* sp.	B (64")	$1x10^9$
	Yersinia enterocolitica	B	$3x10^7$
	Enterobacter gergoviae	C (80")	$1x10^9$
	Klebsiella pneumoniae	C	$8x10^7$
	Yersinia intermedia	C	$5x10^8$

LOG OF LYSIMETER FINDINGS: TEST CELL 11
Physical Conditions

CELL CONTENTS: Municipal Refuse Prewetted with Water

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: Good condition, watertight except one location, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Poor condition, bottom surface rough, some gravel embedded in fiberglass, bottom fiberglass appears fibrous, black around sidewall joint, areas of peeling, waterpight
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening, material very damp contents appear like a black tar-like mass with some recognizable items (e.g. cans), many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Bag of Tobacco - Excellent condition
Plastic Doll - Face entirely black, body some areas of black
Stuffed Toys - Poor condition, obvious degradation
Books - Very poor condition, writing and colors very faded, binding falling apart, still legible
Five and Ten Dollar Bills - (Found inside coin purse), Fronts very good condition, Backs faded but still very legible
Readily Identifiable Organic Products - Green grass clippings, hot dogs, bread, cheese, orange, carrots, potatoes
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 12
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Electroplating Waste

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: (Plywood lid) seal was open, not watertight, not gas tight
Seal around water infiltration line: Cracked
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Poor condition, bottom surface rough, some peeling and cracking, bottom very dark, side had some peeling and fiberglass split in several places
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening, material very damp contents appear like a black tar-like mass with some recognizable items (e.g. cans), no evidence of plating waste, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Paint Bucket - Paint still in bucket
Small plastic Items - No apparent degradation
Aluminum Ice Tray - No apparent degradation
Readily Identifiable Organic Products - Beef patty, bread, carrots, fish head, pickles, green grass, green vegetables, bones
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 12
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 12 inches	Sample B 26 inches	Sample C 60 inches
Total Coliforms	1.59×10^3	9.64×10^2	5.56×10^1
Fecal Coliforms	$< 5.00 \times 10^1$	$< 7.00 \times 10^1$	$< 5.56 \times 10^1$
Fecal Streptococci	7.50×10^3	8.21×10^3	4.72×10^5
C. perfringens (SF)	1.79×10^7	4.64×10^5	5.00×10^7
C. perfringens (TSC)	2.73×10^6	1.43×10^5	8.89×10^6
Total Plate Count (aer)	3.18×10^{10}	3.93×10^{10}	1.53×10^{10}
Total Plate Count (an)	1.61×10^9	2.89×10^{10}	6.94×10^7
Gram Negative Rods	2.73×10^{10}	5.36×10^9	2.08×10^{10}
Fungi	4.77×10^8	1.14×10^7	9.72×10^6

* Diaper NA: Not analyzed

METHANE PRODUCTION

Inoculum Sample Level	Inoculum Wet Weight (grams)	Gas Composition of Culture Vials %CO_2	%O_2	%N_2	%CH_4
12A	5.0	44.30	0.23	7.02	48.45
	0.5	22.95	0.18	6.56	70.31
	0.05	97.33	0.0	1.48	1.19
	0.005	43.95	0.18	6.27	49.60
	0.0	76.50	0.76	22.74	0.0
12B	5.0	50.11	0.49	3.20	46.20
	0.5	37.23	0.36	17.50	44.90
	0.05	38.06	0.27	12.18	49.49
	0.005	66.28	2.69	29.45	1.57
	0.0	85.38	0.32	14.30	0.00
12C	5.0	43.85	0.15	8.86	47.14
	0.5	43.09	0.32	12.49	44.10
	0.05	40.16	0.39	16.97	42.48
	0.005	28.89	0.34	16.63	54.14
	0.0	68.10	1.05	30.85	0.0

LOG OF LYSIMETER FINDINGS: TEST CELL 12
Microbiology

MICROORGANISMS IDENTIFIED

Microbial Type	Microbial Identification	Sample Level (Inches into Refuse)	Concentration (CFU/100g wet)
Clostridium	*C. perfringens*	A (12")	$6x10^{5}$
	C. sordellii	A	$5x10^{6}$
	C. sp.	C (60")	$1x10^{8}$
	C. bifermentans	C	$8x10^{6}$
	C. botulinum (Group I)	C	$1x10^{8}$
	C. cadaveris	C	$1x10^{7}$
	C. difficile	C	$8x10^{6}$
	C. perfringens	C	$9x10^{6}$
Fungi	Yeast	A (12")	$2x10^{5}$
	Demphite	B (26")	$1x10^{5}$
	Yeast	B	$4x10^{4}$
	Cephalosporium sp.	C (60")	$1x10^{5}$
Gram Negative Rods	*Hafnia alvei*	B (26")	$1x10^{9}$
	Aeromonas hydrophila	C (60")	$5x10^{7}$
	Hafnia alvei	C	$5x10^{7}$
	Pseudomonas maltophilia	C	$4x10^{7}$

LOG OF LYSIMETER FINDINGS: TEST CELL 13
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Inorganic Pigment Sludge

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: (Plywood lid) seal was open, not watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Slight bubbling, no apparent peeling
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: Very strong odor upon opening, earthworms found in top gravel and clay layers (probably washed in through open lid), cell appeared slightly drier than other cells, pigment waste dispersed, appears wet and sticky, some evidence of sludge in clumps, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Books and Magazines - Wet, legible, colors still clear
Wooden Toys - Intact, very discolored
38 Special Ammunition - Live, good condition, no apparent degradation
Paintbrush - Intact, bristles good condition, metal had no apparent attack
Gummed Labels - Color and printing like new, gum still servicable
Readily Identifiable Organic Products - Meat, carrots, green grass, corn on the cob, chicken, 4 pints of blood plasma, wig
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 13
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A* 28 inches	Sample B 60 inches	Sample C 86 inches
Total Coliforms	2.47×10^{7}	4.15×10^{2}	8.48×10^{3}
Fecal Coliforms	2.50×10^{2}	$< 4.00\times10^{1}$	$< 6.00\times10^{1}$
Fecal Streptococci	5.31×10^{3}	3.77×10^{2}	7.27×10^{3}
C. perfringens (SF)	4.06×10^{7}	1.74×10^{7}	2.39×10^{6}
C. perfringens (TSC)	9.38×10^{5}	4.53×10^{5}	3.94×10^{6}
Total Plate Count (aer)	4.06×10^{9}	2.08×10^{9}	3.33×10^{7}
Total Plate Count (an)	1.88×10^{10}	1.75×10^{9}	3.03×10^{7}
Gram Negative Rods	1.44×10^{8}	7.17×10^{7}	6.97×10^{5}
Fungi	1.72×10^{7}	1.66×10^{7}	9.70×10^{5}

* Diaper NA: Not analyzed

METHANE PRODUCTION

Inoculum		Gas Composition of Culture Vials			
Sample Level	Wet Weight (grams)	$\%CO_2$	$\%O_2$	$\%N_2$	$\%CH_4$
13A Diaper	5.0	42.85	0.29	10.86	46.00
	0.5	47.97	0.29	14.96	36.78
	0.05	48.12	0.40	21.55	29.93
	0.005	52.74	0.31	15.45	31.50
	0.0	74.31	0.47	25.22	0.0
13B	5.0	44.29	0.18	11.92	43.61
	0.5	48.21	0.25	13.58	37.96
	0.05	45.79	0.33	16.25	37.63
	0.005	57.10	0.33	19.25	23.32
	0.0	analytical problem with blank			
13C	5.0	42.43	0.06	9.55	47.96
	0.5	41.64	0.26	16.06	42.04
	0.05	43.78	0.21	15.41	40.60
	0.005	54.73	0.28	18.96	26.03
	0.0	76.91	0.57	22.52	0.0

LOG OF LYSIMETER FINDINGS: TEST CELL 13
Microbiology

MICROORGANISMS IDENTIFIED

Microbial Type	Microbial Identification	Sample Level (Inches into Refuse)	Concentration (CFU/100g wet)
Clostridium	*C. perfringens*	A (28")*	$4x10^7$
	C. limosum	B (60")	$5x10^4$
	C. perfringens	B	$5x10^5$
	C. bifermentans	C (86")	$7x10^4$
	C. perfringens	C	$5x10^5$
Fungi	*Cladosporium* sp.	A (28")*	$5x10^6$
	Paecilomyces sp.	A	$2x10^7$
	Sepedonium	A	$2x10^6$
	Trichophyton sp.	A	$6x10^4$
	Yeast	A	$2x10^5$
	Aspergillus sp.	B (60")	$1x10^6$
	Paecilomyces sp.	B	$1x10^6$
	Phoma sp.	B	$1x10^6$
	Sepedonium sp.	B	$3x10^6$
	Paecilomyces sp	C (86")	$1x10^5$
	Sepedonium sp.	C	$1x10^5$
Gram Negative Rods	*Klebsiella pneumoniae*	A (28")*	$2x10^7$
	Enterobacter aerogenes	B (60")	$3x10^4$
	Enterobacter agglomerans	B	$1x10^4$
	Enterobacter agglomerans	C (86")	$2x10^4$

* Diaper Sample

LOG OF LYSIMETER FINDINGS: TEST CELL 14
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Chlorine Production Brine Sludge

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:
Seal around lid: seal was open, not watertight, not gas tight
Seal around water infiltration line: Cracked
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Slight bubbling, no apparent peeling
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: Thick layers of sludge still in plastic bags

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening, earthworms found in top gravel and clay layers, sludge still in plastic bags, very little mixing or intermingling of sludge and refuse, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Metal Folding Chair - Very poor condition, obvious degradation
Baseball Bat - Intact, grayish color
Home Communion Service - Small amount of attack on plating, otherwise like new
Oil Paintings - Colors vivid, paper wet and darkened but intact
Lipstick - Tubes and lipstick intact
Readily Identifiable Organic Products - Meat, bread, kale, beans, carrots, potatoes
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 14
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 30 inches	Sample B 66 inches	Sample C 92 inches
Total Coliforms	6.50×10^{2}	2.88×10^{5}	5.67×10^{3}
Fecal Coliforms	2.00×10^{3}	6.88×10^{4}	1.10×10^{3}
Fecal Streptococci	1.00×10^{3}	2.47×10^{4}	2.63×10^{4}
C. perfringens (SF)	8.25×10^{5}	1.69×10^{7}	1.03×10^{6}
C. perfringens (TSC)	9.25×10^{5}	2.97×10^{6}	1.30×10^{6}
Total Plate Count (aer)	4.25×10^{10}	5.31×10^{10}	3.17×10^{10}
Total Plate Count (an)	2.45×10^{10}	3.12×10^{10}	1.83×10^{10}
Gram Negative Rods	2.75×10^{10}	2.84×10^{10}	1.77×10^{6}
Fungi	2.75×10^{5}	1.72×10^{7}	3.67×10^{7}

* Diaper NA: Not analyzed

METHANE PRODUCTION

Sample Level	Inoculum Wet Weight (grams)	Gas Composition of Culture Vials $\%CO_2$	$\%O_2$	$\%N_2$	$\%CH_4$
14A	5.0	lids blew off vials			
	0.5	43.11	0.38	20.79	35.73
	0.05	43.59	0.34	19.04	37.03
	0.005	41.55	0.26	16.95	41.24
	0.0	67.68	0.55	31.77	0.0
14B	5.0	41.76	0.35	16.91	40.98
	0.5	42.04	0.33	16.25	41.38
	0.05	45.68	0.39	19.41	34.52
	0.005	50.00	0.39	18.05	31.56
	0.0	75.96	0.46	23.85	0.0
14C	5.0	40.19	0.31	15.69	43.81
	0.5	47.38	0.14	12.96	39.52
	0.05	43.84	0.29	14.63	41.24
	0.005	46.07	0.27	14.73	38.93
	0.0	71.94	0.48	27.58	0.0

LOG OF LYSIMETER FINDINGS: TEST CELL 14
Microbiology

MICROORGANISMS IDENTIFIED

Microbial Type	Microbial Identification	Sample Level (Inches into Refuse)	Concentration (CFU/100g wet)
Clostridium	*C. botulinum* (Group II)	A (30")	$8x10^{4}$
	C. bifermentans	C (92")	$1x10^{4}$
Fungi	*Aspergillus flavus*	A (30")	$1x10^{4}$
	Penicillium sp.	A	$3x10^{6}$
	Rhizopus sp.	A	$1x10^{4}$
	Trichophyton sp.	A	$2x10^{6}$
	Aspergillus niger	B (66")	$1x10^{4}$
	Trichophyton	B	$1x10^{6}$
	Penicillium sp.	C (92")	$1x10^{6}$
	Trichophyton sp.	C	$2x10^{6}$
Gram Negative Rods	*Vibrio fluvialis*	A (30")	$1x10^{8}$
	Aeromonas hydrophila	B (60")	$1x10^{7}$
	Enterobacter agglomerans	B	$6x10^{7}$
	Enterobacter cloacae	B	$1x10^{9}$
	Klebsiella ozaenae	B	$1x10^{8}$
	Vibrio fluvialis	B	$1x10^{8}$

LOG OF LYSIMETER FINDINGS: TEST CELL 15
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Polio Virus Addition

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: Many breaches, not watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: Bottom slightly rough, 1/4 of bottom black, slight bubbling on sides, still watertight
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening, refuse very far along in decomposition, cans very decomposed, less paint apparent on exposed items, fewer identifiable items, no green grass, some paper and plastic bags with refuse intact, some readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Newspaper - Writing still legible
Pine Cones - Good condition
Readily Identifiable Organic Products - cheese
Cloth - Fibers tear easily, colors fading
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 16
Physical Conditions

CELL CONTENTS: Municipal Refuse

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: 1.05×10^{-2}

SPECIFIC YIELD: Short term: 0.911 $ft^3/hr/yd^3$
Total: 0.093 $ft^3/hr/yd^3$

SEALS AND COAL TAR EPOXY:

Seal around lid: good condition, watertight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: No fiberglass, white paint on bottom in excellent condition
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layers

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No odor upon opening, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying, some mold on top pea gravel

SIGNIFICANT ARTIFACTS:

Half Dollar - Very corroded, only a trace of silver left
Readily Identifiable Organic Products - coconut, bones, unopened pepsi (still had bubbles)
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 16
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 12 inches	Sample B* 28 inches	Sample C 44 inches
Total Coliforms	5.92×10^{5}	8.96×10^{3}	1.26×10^{5}
Fecal Coliforms	$< 7.50 \times 10^{1}$	$< 7.00 \times 10^{1}$	1.16×10^{2}
Fecal Streptococci	8.15×10^{3}	$< 7.00 \times 10^{1}$	8.14×10^{4}
C. perfringens (SF)	1.00×10^{6}	1.21×10^{6}	2.14×10^{6}
C. perfringens (TSC)	1.48×10^{6}	1.34×10^{6}	2.79×10^{5}
Total Plate Count (aer)	1.89×10^{9}	3.52×10^{7}	1.12×10^{9}
Total Plate Count (an)	7.04×10^{8}	3.89×10^{9}	2.53×10^{8}
Gram Negative Rods	2.54×10^{7}	6.31×10^{5}	1.17×10^{8}
Fungi	2.41×10^{5}	7.76×10^{4}	5.35×10^{5}

* Diaper NA: Not analyzed

METHANE PRODUCTION

Inoculum Sample Level	Wet Weight (grams)	Gas Composition of Culture Vials $\%CO_2$	$\%O_2$	$\%N_2$	$\%CH_4$
16A	5.0	56.81	0.53	33.47	9.19
	0.5	53.04	0.74	45.11	1.11
	0.05	64.57	0.42	35.01	0.0
	0.005	75.89	0.31	22.92	0.88
	0.0	54.55	0.68	44.77	0.0
16B Diaper	5.0	57.23	0.27	15.33	27.17
	0.5	69.78	0.36	26.04	3.82
	0.05	78.13	0.42	19.64	1.81
	0.005	78.76	0.36	20.88	0.0
	0.0	35.96	0.68	43.35	0.0
16C	5.0	50.22	0.39	29.95	19.44
	0.5	49.26	0.73	49.17	0.84
	0.05	73.71	0.25	18.68	7.36
	0.005	79.26	0.20	20.54	0.0
	0.0	58.88	0.72	47.63	0.77

LOG OF LYSIMETER FINDINGS: TEST CELL 16
Microbiology

MICROORGANISMS IDENTIFIED

Microbial Type	Microbial Identification	Sample Level (Inches into Refuse)	Concentration (CFU/100g wet)
Fungi	*Absidia* sp.	A (12")	1×10^4
	Aspergillus niger	A	1×10^6
	Chaetomium sp.	A	1×10^4
	Cladosporium sp.	A	1×10^4
	Rhodotorula sp.	A	1×10^4
	Yeast	A	1×10^4
	Absidia sp.	B (28")*	1×10^3
	Aspergillus sp.	B	1×10^4
	Chaetomium sp.	B	1×10^3
	Paecilomyces sp.	B	1×10^4
	Penicillium sp.	B	1×10^3
	Rhodotorula sp.	B	6×10^3
	Yeast	B	1×10^3
	Cladosporium sp.	C (44")	1×10^4
	Fonsecaea sp.	C	1×10^4

* Diaper Sample

LOG OF LYSIMETER FINDINGS: TEST CELL 17
Physical Conditions

CELL CONTENTS: Municipal Refuse plus Solvent Base Paint Sludge

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: Gas permeating through fiberglass lip,watertight
Seal around water infiltration line: Cracked
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: No fiberglass, white paint on bottom in excellent condition
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: Some layering apparent but not wall to wall

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: Strong odor upon opening, paint sludge packed tight with refuse, wet and fairly well decomposed, sludge protected items that would normally be decomposed, sludge very stiff and sticking tightly to items nearby, many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Metal cans - Not entirely intact, obvious degradation
Paper in plastic bag - Partially legible, obvious degradation
Dartboard - Yellow and red colors still clear, black residue on board
Readily Identifiable Organic Products - Chicken with meat on bone, corn
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 17
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 20 inches	Sample B* 50 inches	Sample C* 80 inches
Total Coliforms	4.35×10^{3}	3.83×10^{8}	1.25×10^{6}
Fecal Coliforms	3.48×10^{3}	$< 8.50 \times 10^{2}$	1.18×10^{4}
Fecal Streptococci	1.04×10^{6}	2.04×10^{4}	1.75×10^{4}
C. perfringens (SF)	4.78×10^{7}	9.17×10^{7}	1.93×10^{8}
C. perfringens (TSC)	3.91×10^{5}	8.33×10^{4}	$< 3.60 \times 10^{4}$
Total Plate Count (aer)	1.61×10^{11}	2.20×10^{11}	1.86×10^{10}
Total Plate Count (an)	1.13×10^{9}	1.17×10^{9}	2.43×10^{10}
Gram Negative Rods	7.39×10^{10}	5.10×10^{10}	2.32×10^{9}
Fungi	1.74×10^{5}	8.75×10^{5}	3.57×10^{4}

* Diaper NA: Not analyzed

METHANE PRODUCTION

Inoculum		Gas Composition of Culture Vials			
Sample Level	Wet Weight (grams)	$\%CO_2$	$\%O_2$	$\%N_2$	$\%CH_4$
17A	5.0	61.60	0.52	35.58	2.30
	0.5	49.51	0.60	35.44	14.45
	0.05	71.18	0.40	23.17	5.25
	0.005	62.14	0.53	37.33	0.0
	0.0	76.25	0.42	23.33	0.0
17B Diaper	5.0	69.96	0.30	19.09	10.65
	0.5	56.25	0.71	38.31	4.73
	0.05	58.05	0.53	40.42	1.00
	0.005	62.61	0.28	19.17	17.94
	0.0	54.93	0.72	44.35	0.0
17C Diaper	5.0	lids blew off vials			
	0.5	42.62	0.0	2.58	54.80
	0.05	5.32	0.0	2.75	91.93
	0.005	31.82	0.0	3.00	65.18
	0.0	89.56	0.83	9.61	0.0

LOG OF LYSIMETER FINDINGS: TEST CELL 17
Microbiology

MICROORGANISMS IDENTIFIED

Microbial Type	Microbial Identification	Sample Level (Inches into Refuse)	Concentration (CFU/100g wet)
Clostridium	*C. subterminale*	B (50")*	1×10^3
	C. subterminale	C (80")*	1×10^3
Fungi	*Absidia* sp.	A (20")	1×10^4
	Cladosporium sp.	A	2×10^5
	Penicillium sp.	A	1×10^5
	Yeast	A	1×10^4
	Cladosporium sp.	B (50")*	2×10^5
	Fonsecaea pedrosoi	B	1×10^7
	Paecilomyces sp.	B	1×10^6
	Penicillium sp.	B	5×10^5
	Alternaria sp.	C (80")*	1×10^4
	Aspergillus niger	C	1×10^6
	Cladosporium sp.	C	5×10^5
Gram Negative Rods	*Enterobacter cloacae*	A (20")	3×10^9
	Klebsiella oxytoca	A	4×10^9
	Pseudomonas sp.	A	4×10^8
	Alcaligenes sp.	B (50")*	7×10^9
	Klebsiella oxytoca	B	2×10^8
	Moraxella kingii	B	2×10^8
	Acinetobacter calcoaceticus var. anitratus	C (80")*	5×10^7

* Diaper Sample

LOG OF LYSIMETER FINDINGS: TEST CELL 18
Physical Conditions

CELL CONTENTS: Municipal Refuse

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: Good condition, not watertight, gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: No fiberglass, white painted bottom in excellent condition
Coal Tar Epoxy: Excellent condition, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening, pea gravel and clay layer uneven but refuse layer was even, material very damp contents appear like a black tar-like mass with some recognizable items (e.g. cans), many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Scrub brush - Wooden handle gray but intact, bristles matted
Readily Identifiable Organic Products - Coconut, bone
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 18
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 12 inches	Sample B* 24 inches	Sample C 51 inches
Total Coliforms	2.09×10^{6}	1.20×10^{12}	6.86×10^{11}
Fecal Coliforms	1.23×10^{6}	4.60×10^{6}	1.54×10^{8}
Fecal Streptococci	2.09×10^{6}	6.50×10^{8}	6.86×10^{7}
C. perfringens (SF)	2.09×10^{6}	3.95×10^{8}	7.14×10^{6}
C. perfringens (TSC)	8.30×10^{6}	5.00×10^{4}	1.46×10^{6}
Total Plate Count (aer)	4.59×10^{10}	1.78×10^{10}	6.40×10^{10}
Total Plate Count (an)	7.84×10^{9}	2.18×10^{10}	7.00×10^{9}
Gram Negative Rods	1.29×10^{11}	5.65×10^{12}	2.03×10^{12}
Fungi	5.75×10^{5}	4.02×10^{8}	1.43×10^{8}

* Diaper NA: Not analyzed

METHANE PRODUCTION

Inoculum Sample Level	Inoculum Wet Weight (grams)	Gas Composition of Culture Vials $\%CO_2$	$\%O_2$	$\%N_2$	$\%CH_4$
18A	5.0	52.04	0.54	35.26	12.16
	0.5	59.03	0.55	36.68	3.74
	0.05	57.26	0.54	39.14	3.06
	0.005	69.45	0.28	22.53	7.74
	0.0	55.86	0.78	43.36	0.0
18B Diaper	5.0	63.21	0.47	32.89	3.43
	0.5	42.56	0.47	20.31	36.66
	0.05	54.99	0.62	39.56	4.83
	0.005		lids blew off vials		
	0.0	80.60	0.35	19.05	0.00
18C	5.0	32.20	0.0	1.44	66.36
	0.5		lids blew off vials		
	0.05	41.04	0.0	3.11	55.85
	0.005	37.40	0.0	2.39	60.21
	0.0	76.91	0.93	5.46	16.70

LOG OF LYSIMETER FINDINGS: TEST CELL 18
Microbiology

MICROORGANISMS IDENTIFIED

Microbial Type	Microbial Identification	Sample Level (Inches into Refuse)	Concentration (CFU/100g wet)
Clostridium	C. botulinum	A (12")	1×10^{4}
	C. hastiforme	A	2×10^{8}
	C. histolyticum	A	2×10^{5}
	C. novyi Type A	A	1×10^{4}
	C. perfringens	A	9×10^{6}
	C. perfringens	B (24")*	1×10^{4}
	C. histolyticum	C (51")	3×10^{6}
	C. perfringens	C	1×10^{6}
Fungi	Aspergillus niger	A (12")	1×10^{6}
	Cladosporium sp.	A	5×10^{8}
	Epidermophyton floccosum	A	1×10^{4}
	Fonsecaea compactum	A	5×10^{7}
	Paecilomyces sp.	A	1×10^{4}
	Penicillium sp.	A	1×10^{4}
	Alternaria sp.	B (24")*	1×10^{5}
	Aspergillus flavus	B	1×10^{6}
	Cephalosporon sp.	B	1×10^{8}
	Cladosporium sp.	B	1×10^{8}
	Penicillium sp.	B	5×10^{5}
	Pencillium sp.	C (51")	1×10^{8}
Gram Negative Rods	Alcaligenes sp.	A (12")	5×10^{9}
	Citrobacter freundii	A	7×10^{9}
	Vibrio fluvialis	A	1×10^{10}
	Acinetobacter calcoaceticus var. lwoffi	B (24")*	2×10^{8}
	Klebsiella pneumoniae	B	7×10^{7}
	Pseudomonas sp.	B	1×10^{9}
	Vibrio fluvialis	B	4×10^{9}
	Citrobacter freundii	C (51")	5×10^{7}
	Pseudomonas sp.	C	5×10^{8}
	Vibrio fluvialis	C	2×10^{9}

LOG OF LYSIMETER FINDINGS: TEST CELL 19
Physical Conditions

CELL CONTENTS: Municipal Refuse

MOISTURE ADDITION: 400 mm/yr

PERMEABILITY: Not applicable

SPECIFIC YIELD: Not applicable

SEALS AND COAL TAR EPOXY:

Seal around lid: Sealant cracked and dry, not watertight, not gas tight
Seal around water infiltration line: Cracked, not gas tight
Seal around gas and temperature probes: Cracked
Seal around bottom: Good condition, watertight
Fiberglass: No fiberglass, white paint on bottom in excellent condition
Coal Tar Epoxy: Excellent condition, one streak at top where epoxy was gone, probably burned off at sealing of lid, no apparent deterioration

EVALUATION OF LAYERS: No distinct layering

BOTTOM GRAVEL: Excellent condition, some easily removable black residue, when cleaned gravel like original condition

GENERAL CONDITION OF CELL CONTENTS: No strong odor upon opening, some mold on pea gravel, ferric hydroxide on top pea gravel from rusting at area where coal tar epoxy removed, contents appear like a black tar-like mass with some recognizable items (e.g. cans), many paper and plastic bags with refuse intact, many readily identifiable items after cleaning, sorting and classifying

SIGNIFICANT ARTIFACTS:

Telephone Book - Intact and legible
Readily Identifiable Organic Products - Leaves, cheese, ketchup, corn
Cloth - Synthetic and protected natural fibers still strong, unprotected natural fibers weak, colors still clear
Disposable Diapers - With fecal matter

LOG OF LYSIMETER FINDINGS: TEST CELL 19
Microbiology

LEVELS OF INDICATOR ORGANISMS
Colonies/100 grams dry weight

Depth into Refuse	Sample A 12 inches	Sample B* 28 inches	Sample C 40 inches
Total Coliforms	NA	1.38x10^5	1.10x10^5
Fecal Coliforms	NA	< 5.10x10^1	3.95x103
Fecal Streptococci	NA	2.02x10^7	3.95x10^4
C. perfringens (SF)	NA	2.36x10^7	4.60x10^9
C. perfringens (TSC)	NA	2.82x10^5	2.50x10^7
Toal Plate Count (aer)	NA	3.08x10^7	7.00x10^7
Total Plate Count (an)	NA	3.08x10^7	6.00x10^7
Gram Negative Rods	NA	6.15X10^5	3.00X10^6
Fungi	NA	< 2.60X10^4	1.00X10^7

* Diaper NA: Not analyzed

APPENDIX B. MICROBIOLOGICAL MEDIA AND REAGENTS

MEDIA AND REAGENTS

API-20A

Analytab Products, Plainview, New York, 11803.

API-20E

Analytab Products, Inc., Plainview, New York 11803.

Azide Dextrose Broth

Difco Laboratories, Detroit, Michigan.

Blood Agar

• Blood agar base (Difco)	40	g
Deionized distilled water	1	L

Sterilized at 121°C for 15 minutes. Cool to 50°C and add 50 ml of sheep defibrinated blood from Flow Laboratories, McLean, Virginia 22102.

For anaerobic bacteria, incubate in a GasPak (BBL) jar.

Blood Agar for Streptococci and Clostridia

• Blood agar base (heart infusion, Difco), prepared	1	L
• Sheep blood (Flow Laboratories)	50	ml

Mix aseptically.

Brain Heart Infusion Agar (Difco)

Brain Heart Infusion Broth (BBL Microbiology Systems, Cockeysville, MD 21030)

Brilliant Green Bile 20% (Difco)

Cellulose Digestion Medium (Cooke, 1967)

•	Yeast extract (Difco)(1%)	10	ml
	NH_4NO_3 (10%)	10	ml
	$MgSO_4 \cdot 7H_2O$ (10%)	3	ml
	KH_2PO_4 (0.1M)	10	ml
	NaOH (0.1N) to give pH 6.1-6.3	2-4	ml
	Deionized distilled water	1	L

Add a strip of Whatman #1 filter paper (1x8cm) to each tube. Autoclave at 121°C for 15 minutes.

Chopped Meat Medium

Dowell and Hawkins (1976)
To store clostridia.

•	Ground meat (fat free)	500	g
	Deionized distilled water	1	L
	1N NaOH	25	ml

Bring to a boil and stir. Cool and refrigerate overnight. Skim off fat. Filter through gauze. Spread out meat to dry.

To the liquid:

•	Deionized distilled water: restore volume to 1 L.		
	Peptone (Difco)	30	g
	Yeast extract (Difco)	5	g
	Potassium phosphate	5	g
	Adjust pH to 7.8 with 1N NaOH		

Dispense meat and liquid to tubes so that the proportion of meat to liquid is 1:4. Add a few grains of iron filings. Sterilize at 121°C for 15 minutes.

Decarboxylase Broth Moeller (Difco)

To test for arginine dihydrolase.

•	Decarboxylase medium base (Difco)	10.5	g
•	L-Arginine (Difco)	10.0	g
	Deionized distilled water	1	L

Sterilize at 121°C for 10 minutes.

EC Medium (Difco)

Egg Yolk Agar

• McClung and Turbe egg yolk agar (Difco) prepared with deionized distilled water sterilized at 121°C for 15 minutes and cooled to 50°C.	900	ml
• Sterile egg yolks, prepared by adding an equal volume of egg yolk and sterile saline solution.	100	ml

Mix aseptically.

m-Enterococcus Agar (Difco)

Eosin Methylene Blue Agar (Difco)

Ethyl Violet Azide Broth (Difco)

Gases

To grow clostridia and methane bacteria.

- Carbon dioxide, +99% pure
- Hydrogen, 99.95% pure
- Nitrogen gas, 99.7% pure

These were purchased from the Linde Division, Union Carbide Corporation, Charleston, West Virginia.

Gases - Standards used in gas chromatograph

Mixture:

- Carbon dioxide, mole percentage, 34.71%
- Oxygen, 4.15%
- Methane, mole percentage, 44.67%
- Nitrogen, 16.47%

Matheson Gas Co., Dayton, Ohio

Gram Stain

- Burke and Kopeloff - Beerman Modification (Society of American Bacteriologists, 1957).

Heart Infusion Agar (Difco)

Hydrogen Peroxide (3%)

Inhibitory Mold Agar (BBL)

To grow fungal pathogens, especially the deep-seated fungi.

Iron Milk

Dowell and Hawkins (1976)

• Skim milk powder (BBL)	100	g
Iron wire, 2 cm	1	per tube
Deionized distilled water	1	L

Sterilize at 115°C for 20 minutes.

Karung's Medium

Karung and Yegim (1954)

To aid in demonstrating dimorphism of *Blastomyces*, *Hystoplasma*, and *Sporothrix*.

• Potato flour	1	g
Distilled water	100	ml

Heat until the flour congeals. Sterilize at 121°C for 15 minutes. Cool. Add egg to the mixture. Tube and inspissate in a slanting position for 1 hour at 90°C.

KF Streptococcal Agar (BBL)

Lactophenol Cotton Blue Stain

Conant et al. (1971)
To stain the mold hyphae.

• Phenol crystals	20	g
Lactic acid	20	ml
Glycerol	40	ml
Distilled water	20	ml

Dissolve under hot tap water. Add 0.05 g cotton blue.

Lauryl Sulfate Broth (BBL)

Lugol's Iodine

Society of American Bacteriologists (1957)
For starch hydrolysis.

MacConkey Agar (BBL)

0.1% Methylene Blue in Skim Milk

Bordner et al. (1978)

• Skim Milk Powder (BBL)	100	g

Methylene Blue Powder	1	g
Distilled Water	1	L

Heat to dissolve. Sterilize at 115°C for 20 minutes.

Methanogenesis Medium

Donnelly and Scarpino (1984)
Enrichment broth for methane-producing bacteria.

• Sewage Sludge	300	ml
KH_2PO_4	0.5	g
K_2HPO_4	0.5	g
NaCl	1.0	g
$(NH_4)_2SO_4$	0.5	g
$MgSO_4 \cdot 7H_2O$	6.2	g
$CaCl_2 \cdot 2H_2O$	0.13	g
Reasurin	0.001	g
$MnSO_4 \cdot H_2O$	0.5	g
$FeSO_4 \cdot 7H_2O$	0.2	g
$CoCl_2 \cdot 6H_2O$	0.17	g
$ZnSO_4 \cdot 7H_2O$	0.18	g
$CuSO_4 \cdot 5H_2O$	0.02	g
$Na_2SO_4 \cdot 12H_xO$	0.018	g
H_3BO_4 (Boric Acid)	0.01	g
$Na_2MoO_4 \cdot 2H_2O$	0.01	g
Trypticase (or tryptone)	2.0	g
Yeast Extract	2.0	g
Na Formate	2.0	g
Na Acetate	2.0	g
Water	700	ml

Place 100 ml of medium in 150 ml glass vials and flush with oxygen-free nitrogen. Sterilize at 121°C for 15 minutes. Re-flush with oxygen-free nitrogen and secure mouth of vials with serum sleeve rubber stoppers. Cool.

• 50% $NaHCO_3$	0.25	ml
• *Escherichia coli* ATCC 13706, overnight culture grown at 37°C in brain heart infusion broth.	0.50	ml

Mineral Oil

Society of American Bacteriologists (1957)
Sterilize in 100 ml amounts at 121°C for 60 minutes.

Motility Test Medium

• Motility Test Medium (Difco)	20	g
• Deionized Distilled Water	1	L

Cooled to 50°C following sterilization at 121°C for 15 minutes. Add

TTC solution.

- 1% TTC Solution, prepared with Bacto-TTC 5 ml (2,3,5-Triphenyl tetrazolium chloride and deionized distilled water) and membrane filter sterilized before use.

Mycosel Agar (BBL)

To isolate the dermatophytes.

Oxidase Test Reagents

N,N,N[1],N[1]-tetramethyl-p-phenylenediamine dihydrochloride, 1% solution in droppers. Manufactured by Marion Scientific Corporation, Kansas City, Missouri 64114.

Oxidation-Fermentation Test Medium

• OF Basal Medium (BBL) prepared	900	ml
• 10% glucose aqueous solution, sterilized by membrane filtration.	100	ml

Mix aseptically. After inoculation, overlay each tube with sterile mineral oil.

(0.1%) Peptone Water

Standard Methods (1980)
A diluent for bacterial cultures

• Bacto-peptone (Difco)	1.0	g
Deionized distilled water	1	L

Sterilized at 121°C for 15 minutes.

pH 9.6, Brain Heart Infusion Broth

Bordner et al. (1978)

• Brain Heart Infusion Broth (BBL) with the addition of enough $Na_3PO_4 \cdot 12H_2O$ to produce a final pH of 9.6.	1	L

Phosphate Buffer

Standard Methods (1981)

Potato Dextrose Agar (BBL)

PSE Agar - (Bile Esculin Azide Agar- Gibco Laboratories, Madison, WI 53713)

Sabouraud Agar, Modified (Difco)

Saline

• Sodium chloride	8.5	g
deionized distilled water	1	L

Sterilized at 121°C for 15 minutes.

6.5% Sodium Chloride in Brain Heart Infusion Broth

Bordner et al. (1978)

• Brain heart infusion broth (BBL) prepared	1	L
• Sodium chloride	65	g

Mix and autoclave at 121°C for 15 minutes.

Starch Agar

Bordner et al. (1978)

• Peptone (Difco)	10	g
Yeast extract (Difco)	5	g
Sodium chloride	5	g
Starch (soluble)	2	g
Agar (Difco)	15	g
Deionized distilled water	1	L

Heat to dissolve. Sterilize at 121°C for 15 minutes.

Standard Methods Agar (BBL)

Sodium Hippurate Broth

Facklam et al. (1974)
To identify Group B streptococci.

• Heart infusion broth (Difco)	25.0	g
Sodium hippurate	10.0	g
Distilled water	1	L

Sterilize at 121°C for 15 minutes.

• Test Solution:		
$FeCl_3 \cdot 6H_2O$	12	g

HCl, 21% prepared by 5.4 ml of concentrated HCl to 94.6 ml of deionized distilled water.	100	ml

0.04% Potassium Tellurite Agar

Bordner et al. (1978)
To inhibit streptococcal contaminants.

• Brain heart infusion agar (Difco), prepared, sterilized and cooled to 50°C.	1	L
• 4% potassium tellurite, sterilized by membrane filtration.	10	ml

Mix.

Thioglycollate Medium without Indicator - 135°C (BBL)

(Dowell and Hawkins (1976)

• Thioglycollate 135-C	30	g
Calcium carbonate	1	g
Deionized distilled water	1	L

Sterilize at 118°C for 15 minutes.

Trypticase Soy Agar (BBL)

Trypticase Soy Broth (BBL)

Tryptone Sulfite Cycloserine (TSC) Agar

Duncan and Harmon (1976)
To enumerate *Clostridium perfringens*

• Trypticase soy broth (BBL)	30.0	g
Sodium metabisulfite	1.83	g
Ferric ammonium citrate	1.0	g
Agar (Difco)	20.0	g
Yeast extract	5.0	g
Distilled water	1	L

Heat to dissolve ingredients. Adjust pH to 7.6. Sterilize at 121°C for 10 minutes. Cool to 50°C. To each liter of medium, add 10 ml of 4.0% D-cycloserine (sterilized by the membrane filter) and 80 ml of sterile 50% egg yolk in saline.

TTC Agar

Bordner et al. (1978)
To inhibit streptococcal contaminants.

• Peptone (Difco)	10	g
Beef extract (Difco)	10	g
Sodium chloride	5	g
Agar	14	g
Deionized distilled water	1	L
Final pH: 7.0 -7.3		

Autoclave at 121°C for 15 minutes.

• 1% TTC solution: (2,3,5-triphenyl tetrazalium chloride) (Difco) filter sterilized.	10	ml
• 50% glucose solution sterilized by membrane filter.	20	ml

APPENDIX C. SAMPLE DEPTHS

TEST CELL	SAMPLE	DEPTH FROM TOP Inches	DEPTH FROM TOP Centimeters	DEPTH INTO REFUSE Inches	DEPTH INTO REFUSE Centimeters
1	A	68	173	17	43
	B	112	285	61	155
	C	128	325	77	196
2	A	72	183	23	58
	B	102	259	53	135
	C	126	320	77	196
3	A	66	168	16	41
	B	96	244	46	117
	C	126	320	76	193
4	A	76	193	26	66
	B	103	262	53	135
	C	136	345	86	218
5	A	90	229	40	102
	B	111	282	61	155
	C	120	305	70	178
6	A	68	173	19	48
	B	107	272	57	145
	C	132	335	82	208
7	A	76	193	30	76
	B	106	269	60	152
	C	138	351	92	234
8	A	67	170	24	61
	B	105	267	62	157
	C	125	318	82	208

(Continued on next page)

SAMPLE DEPTHS (Cont.)

TEST CELL	SAMPLE	DEPTH FROM TOP Inches	DEPTH FROM TOP Centimeters	DEPTH INTO REFUSE Inches	DEPTH INTO REFUSE Centimeters
9	A	67	170	22	56
	B	91	231	46	117
	C	121	307	76	193
10	A	95	241	44	112
	B	115	292	64	163
	C	131	333	80	203
11	A	78	198	28	71
	B	130	330	80	203
	C	136	345	86	218
12	A	62	158	12	31
	B	76	193	26	66
	C	110	279	60	152
13	A	70	178	28	71
	B	102	259	60	152
	C	128	325	86	218
14	A	72	183	30	76
	B	108	274	66	168
	C	132	335	92	234
15	A	83	211	14	36
	B	113	287	44	112
	C	138	351	69	175
16	A	74	188	12	31
	B	90	229	28	71
	C	106	269	44	112
17	A	69	175	20	51
	B	99	252	50	127
	C	129	328	80	203
18	A	81	206	12	31
	B	93	236	24	61
	C	120	305	51	130
19	A	75	191	12	31
	B	91	231	28	71
	C	103	262	40	102

APPENDIX D. SUPPLEMENTAL MICROBIOLOGICAL ANALYSES

Some additional microbiological analyses were conducted in order to obtain more specific information on the fungi and the Streptococcus species isolated in the lysimeters. These analysis were only performed on selected cells and, therefore, have been included in this appendix rather than in the main body of the report.

CELLULOSE DIGESTION

The results from Table D-1 show that the majority of mold isolates digested the filter paper to some degree. Approximately 30% of those completely digested the filter paper. Of the 61 digested, almost all grew within the media, but did not digest the filter paper beneath the surface of the liquid medium. Most, but not all, of the digestion began at the liquid medium/air contact. Many also digested the paper filter above the liquid up to seven centimeters. Aluminum tops were placed on the tube opening to insure an adequate amount of air was available. However, in the lysimeter under anaerobic conditions, these optimum conditions may not be available and digestion may not occur at such speed.

IDENTIFICATION STREPTOCOCCI

The surviving streptococcal groups and species indicate that they came from cow's milk, animal (human, horse, or bovine) life, chickens or other fowl, and human feces. Of course, 24 isolates per sample of solid waste cannot produce significant percentages for the lysimeters, but they can suggest that a variety of Streptococci are present which came from animal sources. This may be due to foods, pet feces, human nasal secretions from hankerchief-like tissues, and human diaper feces. It suggests further that additional studies on streptococcal identification could yield species. Also, this varied survival indicates the variety of waste placed in the lysimeters. Far from getting rid of unwanted microorganisms, they may instead be stored in some variety.

TABLE D-1. ENUMERATION OF MOLD ISOLATES FROM LYSIMETER SOLID WASTE WHICH DIGEST CELLULOSE

LYSIMETER NUMBER	NUMBER OF MOLD ISOLATES	NUMBER OF MOLDS DIGESTING CELLULOSE	% DIGESTING CELLULOSE	FILTER PAPER DIGESTION(cm)[a] LENGTH AVERAGE	FILTER PAPER DIGESTION(cm)[a] RANGE
1[b]	6	2	33	3.5	3.5
3[c]	32	23	71	3.8	0.5 - 7.0
7[c]	16	7	43	2.1	1.0 - 3.5
9[c]	9	3	33	4.0	2.5 - 6.5
10[d]	15	9	60	2.7	1.0 - 5.5
13[d]	2	0	0	0	0
17[c]	23	16	69	2.5	0.5 - 4.0
18[c]	6	1	17	2.0	2.0
TOTAL	109	61			

a - after incubation for three to eleven weeks at room temperature (23°C)
b - incubation was for eleven weeks
c - incubation was for three weeks
d - incubation was for seven weeks

TABLE D-2. STREPTOCOCCAL IDENTIFICATION[a] FOR SOLID WASTE

SOLID WASTE SOURCE LYSIMETER NUMBER	SOLID WASTE SOURCE LEVEL	NUMBER OF ISOLATES	STREPTOCOCCAL IDENTIFICATION	PERCENT
1	C	16	*S. cremones*	67
		1	Bergy's Group II[b]	4
		1	Bergy's Group I	4
		6	*S. uberis*	25
	TOTAL	24		
7	A	11	*S. avium*	46
		7	Bergy's Group II	29
		6	*S. faecalis*	25
	TOTAL	24		

a = Scheme presented in Bergy's Manual (Buchanan and Gibbons, 1974)
b = Bergy's Manual has four groups

TABLE D-3. CHARACTERIZATION OF SOLID WASTE USED FOR MICROBIAL ANALYSES

LYSIMETER NUMBER	SAMPLE LEVEL	PERCENT MOISTURE*	pH	CONDUCTIVITY µ mhos/cm
1	A	70	5.6	266
	B	63	6.0	488
	C	65	6.3	453
3	A	65	5.2	1108
	B	63	6.8	273
	C	63	6.9	463
7	A	60	6.5	534
	B	61	6.5	566
	C	72	6.3	367
9	A	61	6.5	438
	B	50	6.7	499
	C	56	6.5	736
10	A	61	6.8	601
	B	67	6.5	782
	C	63	6.5	1279
12	A	56	6.1	552
	B	72	5.9	261
	C	64	5.8	470
13	A	68	6.6	606
	B	47	6.7	462
	C	67	7.2	411
14	A	60	6.6	358
	B	68	6.4	288
	C	70	6.5	1414
16	A	73	7.4	236
	B	71	6.9	157
	C	57	6.9	207
17	A	77	7.1	250
	B	76	6.8	177
	C	72	6.8	103
18	A	56	7.7	339
	B	80	8.0	502
	C	65	7.6	385
19	B	61	7.8	406
	C	80	8.0	329

*These percent moisture analyses were performed on the small, fine particle-size microbiological samples. These were noted to be generally higher than the percent moisture on the bulk samples.

APPENDIX E. QUALITY ASSURANCE

The data quality criteria that were of concern in this project and which are addressed in this appendix are precision, accuracy, completeness, representativeness and comparability of the data. Each of the following sections describes one of these criteria. Some analyses were performed for which no QA information was generated. The final section summarizes the data quality for all analyses including those analyses without corresponding QA information. This summary discusses problems that were encountered and the overall useability of all of the data.

PRECISION

Precision is defined as the measure of mutual agreement among individual measurements of the same property. This is monitored by comparing the results of split or duplicate samples. The goal is always to minimize the difference between the replicate results. Precision for all analyses has been evaluated two ways. First, as described in "Calculation of Precision, Bias and Method Detection Limit for Chemical and Physical Measurements", the replicate analyses were evaluated for any apparent trends between the mean values and the standard deviation and/or the coefficient of variation of the data pairs or triplicates. In all cases, the coefficient of variation appeared to remain relatively constant for all concentration ranges. Therefore, precision for all analyses has been expressed as a standard deviation derived from the mean coefficient of variation from each data set. The standard deviation is derived from the coefficient of variation according to the following equation:

$$s = CV\,X / 100$$

where: s = standard deviation
CV = coefficient of variation
X = sample concentration

Secondly, the data has been expressed in terms of the % deviation from the mean:

$$\%D = \frac{\overline{X} - X_n}{\overline{X}} \times 100$$

where: $\%D$ = % Deviation from the mean
$\overline{X}$ = Mean Concentration of duplicate results
X_n = One of the duplicate results

This provides some direct indication of how far two duplicate results differ from the reported mean value.

In order to further describe the data, the minimum deviation, maximum deviation, and standard deviation are reported. This information can be loosely interpreted in the following manner. An overall average deviation about the mean of 10% suggests that a reported mean value of 625 mg/l, for example, is derived from duplicate values of 562 mg/l and 688 mg/l. When applied to an entire data set, it could be said that for any duplicate analyses performed of this particular analysis, the reported mean value will, on the average, be ± 10% of the actual values obtained. If the standard deviation of the individual deviations from the mean is 10%, one would further anticipate, based on the assumption of a normal distribution, that 90% of the data would actually fall at or below this estimate of ± 10%. The maximum and minimum deviations give an indication of where the actual values really fall.

COD

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.10X CU, where X is the mean concentration of the duplicate pair and CU represents the concentration units of the result. This estimate is based on duplicate analyses of eight samples which represent approximately 10% of the total samples analyzed. Concentrations ranged from 60.6 mg/l to 18000 mg/l in the leachate and 400 g/kg to 1000 g/kg wet in the refuse.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 1. Mean reported values are, on the average, ± 7% of the actual duplicate data values obtained.

TOC

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.02X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of five samples which represent approximately 6% of the total samples analyzed. Concentrations ranged from 7.00 mg/l to 5000 mg/l in the leachate and from 300 to 900 g/kg wet in the refuse.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 1. Mean reported values are, on the average, ± 1% of the actual duplicate data values obtained.

Chloride

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.12X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analysis of seven samples which represent approximately 9.2% of the total samples analyzed. Concentrations ranged from 18.0 mg/l to 1500 mg/l in the leachate and from 0.500 g/kg to 4.50 g/kg wet in the refuse.

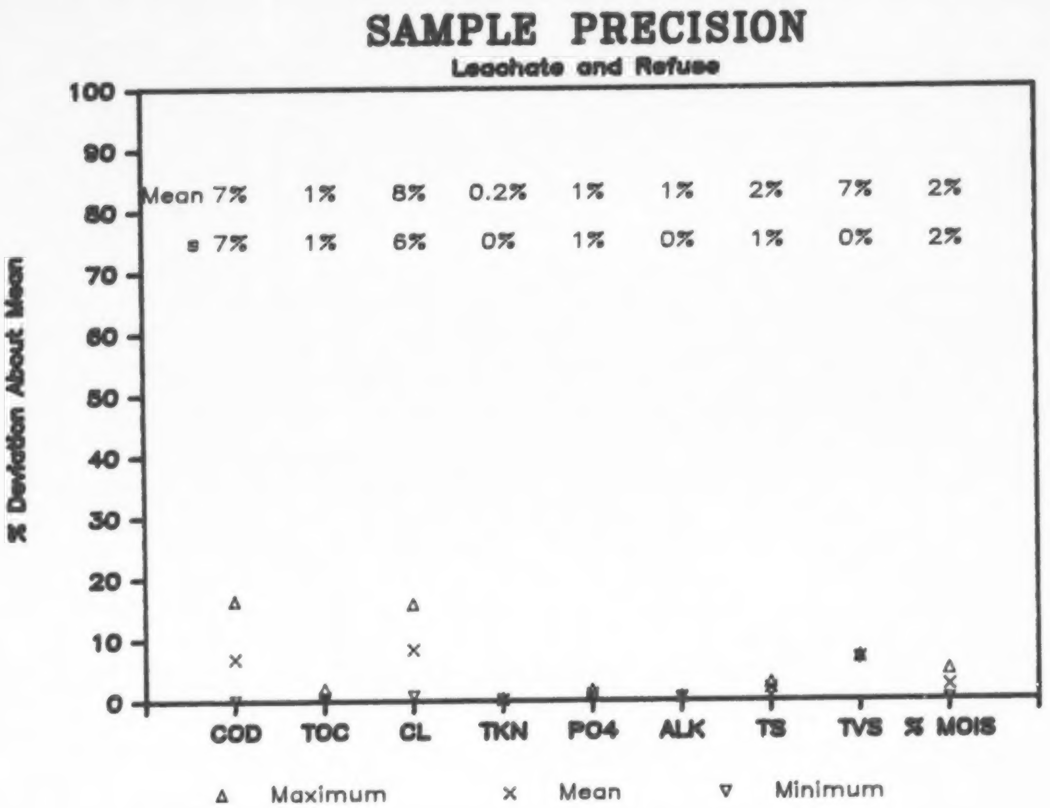

Figure 1.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 1. Mean reported values are, on the average, ± 8% of the actual duplicate data values obtained.

TKN

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.02X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of eight samples which represent approximately 10% of the total samples analyzed. Concentrations ranged from 20 mg/l to 350 mg/l in the leachate and 3.00 g/kg to 13.0 g/kg in the refuse.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 1. Mean reported values are, on the average, ± 0.2% of the actual duplicate data values obtained.

Total Phosphate

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.02X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of two samples which represent approximately 10% of the total samples analyzed. Concentrations ranged from 0.01 mg/l to 30.0 mg/l in the leachate. The refuse was not analyzed for total phosphate.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 1. Mean reported values are, on the average, ± 1% of the actual duplicate data values obtained.

Alkalinity

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.006X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of two samples which represent approximately 10% of the total samples analyzed. Concentrations ranged from 600 mg/l to 6000 mg/l in the leachate. Alkalinity was not determined on the refuse samples.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 1. Mean reported values are, on the average, ± 1% of the actual duplicate data values obtained.

Total Solids

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.03X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of two samples which represent approximately 10% of the total samples analyzed. Concentrations ranged from 1000 mg/l to 10000 mg/l in the leachate. Total solids were not determined on the refuse samples.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 1. Mean reported values are, on the average, ± 2% of the actual duplicate data values obtained.

Total Volatile Solids

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.05X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of two samples which represent approximately 10% of the total samples analyzed. Concentrations ranged from 300 mg/l to 5000 mg/l in the leachate. Total volatile solids were not determined on the refuse samples.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 1. Mean reported values are, on the average, ± 7% of the actual duplicate data values obtained.

% Moisture

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.02X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of five samples which represent approximately 9% of the total samples analyzed. Concentrations ranged from 45% to 70% wet for those refuse samples analyzed.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 1. Mean reported values are, on the average, ± 2% of the actual duplicate data values obtained.

Cadmium

The estimate of intralaboratory, short term precision for all concentrations found in the leachate is s = 0.49X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of two samples which represent approximately 10% of the total leachate samples analyzed. Concentrations in the leachate ranged from less than 0.025 mg/l to 0.117 mg/l. Cadmium concentrations in the refuse ranged from less than 0.005 g/kg to 0.028 g/kg wet. Unfortunately, 61% of the refuse results, including the two duplicate analyses, were reported as less than the detectable limit. Therefore, precision statements do not include any cadmium results from the refuse.

Analysis precision based on the deviation about the mean of the duplicate leachate pairs can be seen in Figure 2. Mean reported values are, on the average, ± 33% of the actual duplicate data values obtained.

Copper

The estimate of intralaboratory, short term precision for all concentrations found in the refuse is s = 0.06X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analysis of two samples which represent approximately 11% of the total samples analyzed. Concentrations ranged from 0.007 g/kg to 1.76 g/kg wet in the refuse. Leachate concentrations ranged from less than 0.025 mg/l to 0.062 mg/l. Approximately 78% of the leachate samples, including the two duplicate analyses, were reported as below detectable limits. Therefore, precision estimates stated here do not directly include data generated from leachate samples, however, leachate duplicates would probably show similar levels of reproducibility.

Analysis precision based on the deviation about the mean of the duplicate refuse pairs can be seen in Figure 2. Mean reported values are, on the average, ± 28% of the actual duplicate data values obtained.

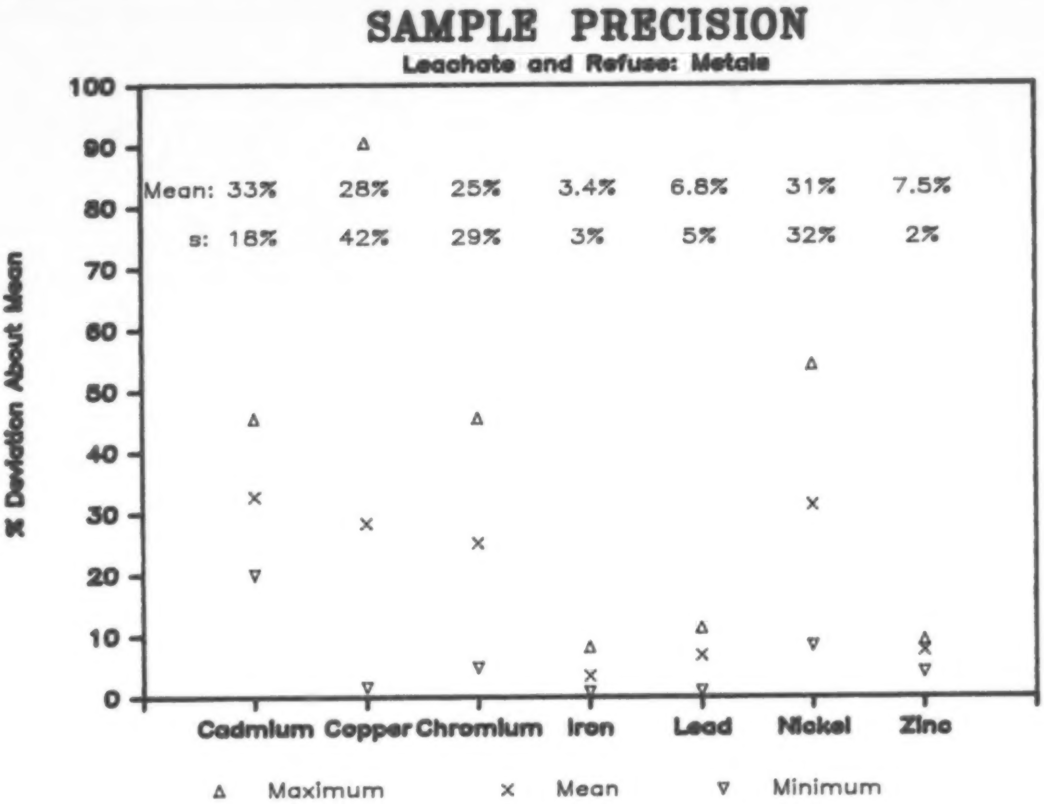

Figure 2.

Chromium

Intralaboratory, short term precision was not quantified for chromium. Concentrations ranged from less than 0.025 mg/l to 0.051 mg/l in the leachate and from 0.031 g/kg to 1.10 g/kg in the refuse. Unfortunately, 61% of the leachate samples, including the two duplicate analyses, were below detectable limits. Refuse duplicates were inadvertently omitted.

In an attempt to obtain some feel for the reproducibility of the chromium results, the analysis precision based on the deviation about the mean of the duplicate leachate pairs was determined even though the results were reported below the detectable limit. Concentrations are often quantifiable below reported detection limits; however, the confidence in these results is very low. Generally, reproducibility would be relatively low at these levels, so precision estimates based on this type of data would tend to be high estimates of the true precision. Precision based on the deviation about the mean can be seen in Figure 2. Mean reported values are on the average, ±25% of the actual duplicate data values obtained.

Iron

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.05X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of four samples which represent approximately 11% of the total samples analyzed. Concentrations ranged from 75.0 mg/l to 2200 mg/l in the leachate and from 10 g/kg to 400 g/kg in the refuse.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 2. Mean reported values are, on the average, ± 3.4% of the actual duplicate data values obtained.

Lead

The estimate of intralaboratory, short term precision for each concentration found in the sample lot is s = 0.10X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analysis of four samples which represent approximately 11% of the total samples analyzed. Concentrations ranged from less than 0.05 mg/l to 0.20 mg/l in the leachate and from 0.02 g/kg to 4.00 g/kg in the refuse.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 2. Mean reported values are, on the average, ± 6.8% of the actual duplicate data values obtained.

Nickel

The estimate of intralaboratory, short term precision for all concentrations found in the leachate is s = 0.41X CU, where X is the mean concentration of the duplicate leachate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of two samples which represent approximately 10% of the total leachate samples analyzed. Concentrations ranged from less than 0.04 mg/l to 0.330 mg/l in the leachate. Duplicate results were not reported for the refuse samples. These samples ranged in concentration from 0.010 g/kg to 0.070 g/kg wet weight.

Analysis precision based on the deviation about the mean of the duplicate leachate pairs can be seen in Figure 2. Mean reported values are, on the average, ± 31% of the actual duplicate data values obtained.

Zinc

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.10X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analyses of three samples which represent approximately 8% of the total samples analyzed. Concentrations rang from less than 0.025 mg/l to 0.720 mg/l in the leachate and from 0.500 g/kg to 4.00 g/kg in the refuse.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 2. Mean reported values are, on the average, ± 7.5% of the actual duplicate data values obtained.

Permeability

The estimate of intralaboratory, short term precision for all concentrations found in the sample lot is s = 0.04X CU, where X is the mean concentration of the triplicate results and CU represents the concentration units of the result. This estimate is based on triplicate analysis of four samples which represent 100% of the total samples analyzed. Concentrations ranged from 0.97×10^{-2} cm/sec to 1.33×10^{-2} cm/sec in the refuse.

Analysis precision based on the deviation about the mean has not been determined for this analysis, since this method of expressing precision is only applicable to duplicate analyses.

Standard Plate Count: Aerobic

Precision measurements of microbiological plate counts are based on the actual counts prior to dilution corrections of the duplicate plates. The estimate of intralaboratory, short term precision for all aerobic standard plate counts recorded in the sample lot is s = 0.16X CU, where X is the mean count of the duplicate plates and CU represents colonies counted. This estimate is based on duplicate analysis of thirty-two samples which represent approximately 97% of the total samples analyzed. The actual plate counts, not corrected for dilutions, ranged from 23 to 1120 in the refuse samples.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 3. Mean reported values are, on the average, ± 13% of the actual duplicate data values obtained.

Standard Plate Count: Anaerobic

The estimate of intralaboratory, short term precision for all counts recorded in the sample lot is s = 0.16X CU, where X is the mean count of the duplicate plates and CU represents colonies counted. This estimate is based on duplicate analyses of thirty-three samples which represent approximately 100% of the total samples analyzed. The actual plate counts, not corrected for dilutions, ranged from 25 to 250 in the refuse samples.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 3. Mean reported values are, on the average, ± 10% of the actual duplicate data values obtained.

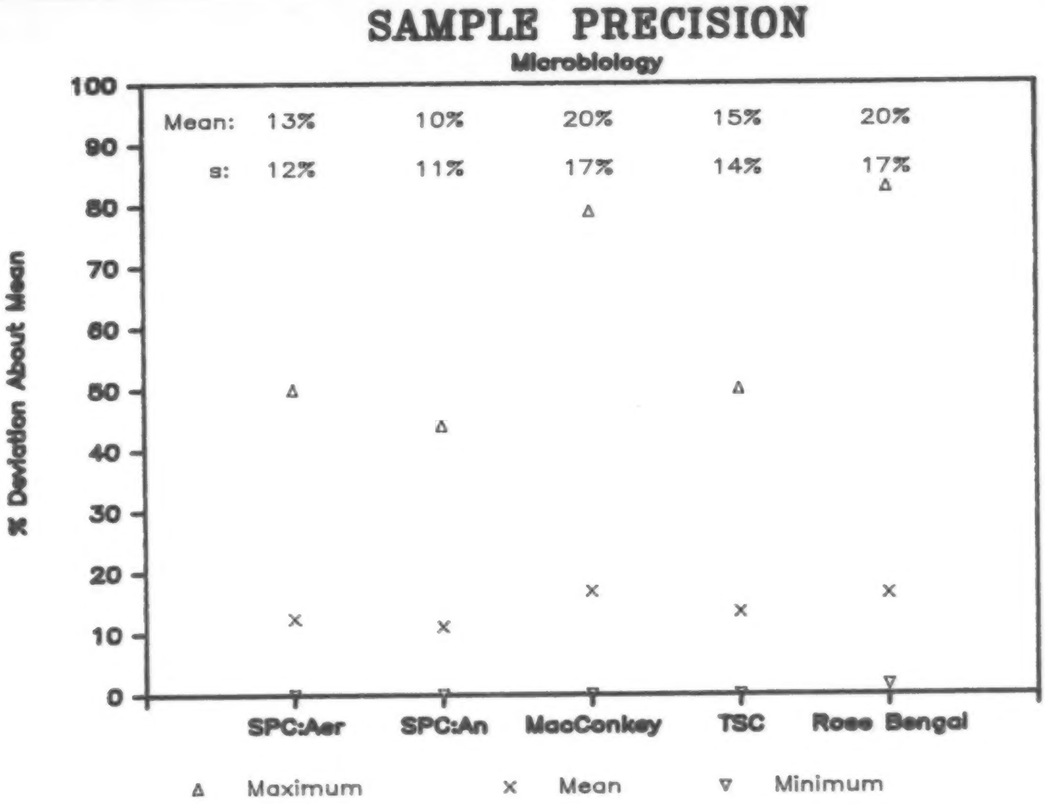

Figure 3.

Gram Negative Rods: MacConkey Agar

The estimate of intralaboratory, short term precision for all counts recorded in the sample lot is s = 0.23X CU, where X is the mean count of the duplicate plates and CU represents colonies counted. This estimate is based on duplicate analyses of thirty-five samples which represent approximately 97% of the total samples analyzed. The actual plate counts, not corrected for dilutions, ranged from 3 to 600 in the refuse samples.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 3. Mean reported values are, on the average, ± 20% of the actual duplicate data values obtained.

Clostridium Perfringens: Tryptone Sulfite Cycloserine Agar

The estimate of intralaboratory, short term precision for all counts recorded in the sample lot is s = 0.19X CU, where X is the mean count of the duplicate plates and CU represents colonies counted. This estimate is based on duplicate analyses of thirty-one samples which represent approximately 94% of the total samples analyzed. The actual plate counts, not corrected for dilutions, ranged from 1 to 130 in the refuse samples.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 3. Mean reported values are, on the average, ± 15% of the actual duplicate data values obtained.

Fungi: Rose Bengal Agar

The estimate of intralaboratory, short term precision for all counts recorded in the sample lot is s = 0.23X CU, where X is the mean count of the duplicate plates and CU represents colonies counted. This estimate is based on duplicate analyses of twenty-nine samples which represent approximately 88% of the total samples analyzed. The actual plate counts, not corrected for dilutions, ranged from 1 to 250 in the refuse samples.

Analysis precision based on the deviation about the mean of the duplicate pairs can be seen in Figure 3. Mean reported values are, on the average, ± 20% of the actual duplicate data values obtained.

Gas Composition (Methane Producers)

The estimate of intralaboratory, short term precision for each concentration found in the sample lot is s = 0.03X CU, where X is the mean concentration of the duplicate pairs and CU represents the concentration units of the result. This estimate is based on duplicate analysis of three samples which represent approximately 2% of the total samples analyzed. Concentrations ranged from 0% to 90% methane in the sample vials.

Analysis precision based on the deviation about the mean of the duplicate pairs has not been included in any figure, since the analysis results were used in a qualitative rather than quantitative manner.

ACCURACY

Accuracy is defined as the degree of agreement of a measurement with the true value of the measurement. Accuracy for this project is estimated in two different ways. First, a measurement of the accuracy of the measurement process is obtained through the analysis of QA standards. If the measurement process is functioning normally, results are expected to fall very close to 100% recovery of the standard. Unfortunately, standards are not available for all analyses and, therefore, in some cases it is not possible to estimate the accuracy of the measurement process. The microbiological analyses fall into this category. There are no standards with known microbial counts to quantitatively assess the validity of the microbial measurements. However, it was possible to qualitatively evaluate the accuracy of the measurement process by evaluating the prepared media against reference cultures. These cultures were derived directly from the American Type Culture Collection or indirectly from Difco. These reference cultures can be seen in Table E-1.

The second way that accuracy is evaluated is through laboratory matrix spikes. This provides information on the presence of interferences due to the sample matrix which enhance or inhibit analyte recovery. These spikes are added to the samples in the lab immediately prior to analysis and therefore reflect interferences encountered in the sample preparation process as well as the actual analysis. Results for both types of accuracy evaluations for those analyses where accuracy quantification was possible are discussed in the following sections.

TABLE E-1. MICROBIOLOGICAL REFERENCE CULTURES

CULTURE NAME	ATCC NUMBER
Acinetobacter calcoaceticus	e23055
Clostridium novyi	e19402
Clostridium perfringens	e3624
Escherichia coli	25922
Pseudomonas aeruginosa	27853
Staphylococcus aureus	29213
Streptococcus faecalis	29212
Streptococcus salivarius	e13419

a: American Type Culture Collection, Rockville, Maryland 20852

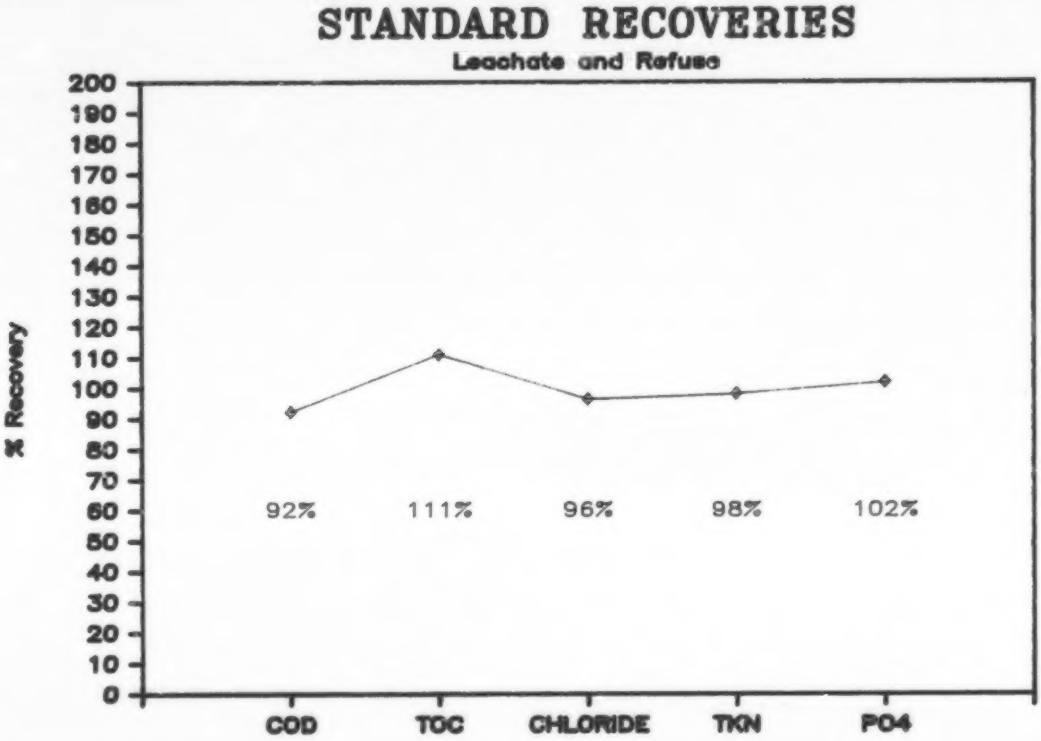

Figure 4.

COD

The average standard recovery based on three standards is 92% with a standard deviation of 3.5% (Figure 4). This suggests that reported results may reflect a small negative bias. Seven samples, representing approximately 9% of the total samples analyzed, were spiked. The mean spike recovery was 100% with a standard deviation of 14% (Figure 5).

TOC

TOC was performed differently on leachate samples than on the refuse samples. Unfortunately, only the method used on the leachate, using a TOC analyzer, was amenable to running standards and spiking. The one standard analyzed had a recovery of 111%. This suggests that reported results may reflect a small positive bias. Two samples, representing approximately 10% of the total samples amenable to spiking, were spiked. The mean spike recovery was 133% with a standard deviation of 45%.

Chloride

The average standard recovery based on three standards is 96% with a

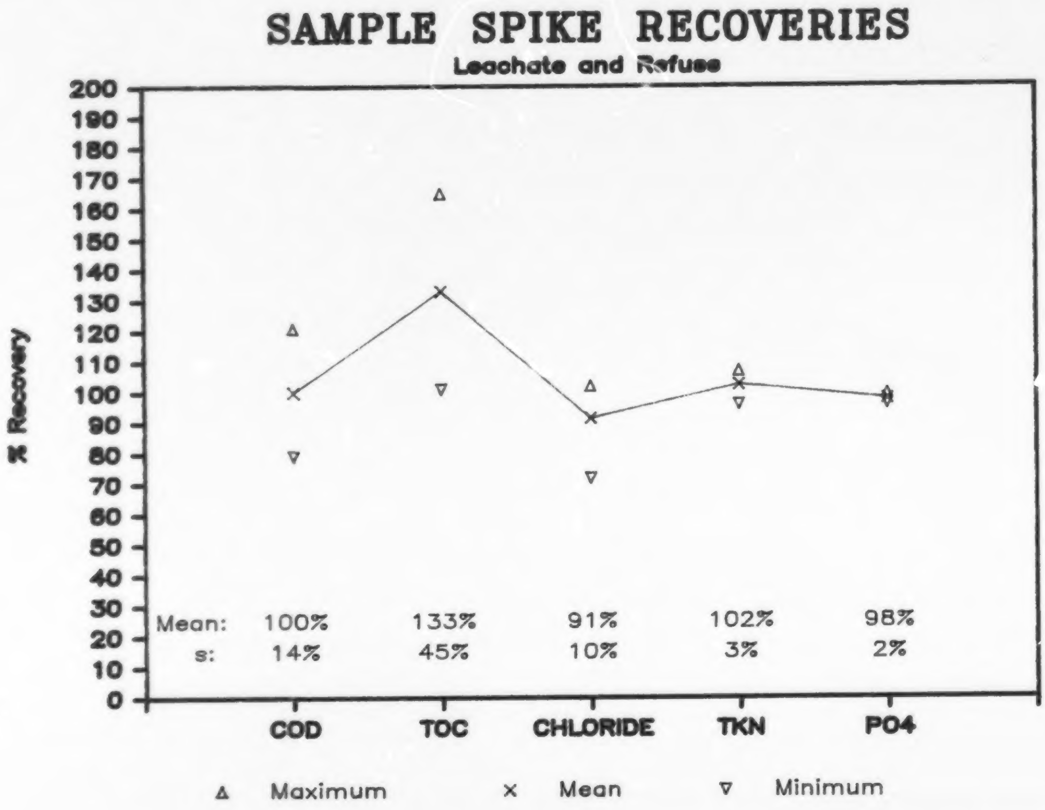

Figure 5.

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standard deviation of 2.1%. This suggests that reported results may reflect a very slight negative bias. Seven samples, representing approximately 9% of the total samples analyzed, were spiked. The mean spike recovery was 91% with a standard deviation of 10%.

TKN

The average standard recovery based on three standards is 98% with a standard deviation of 1.1%. This suggests that reported results essentially reflect no bias. Seven samples, representing approximately 9% of the total samples analyzed, were spiked. The mean spike recovery was 102% with a standard deviation of 3%.

Total Phosphate

The recovery of the one standard analyzed is 102%. This suggests that reported results essentially reflect no bias. Two samples, representing approximately 10% of the total samples analyzed, were spiked. The mean spike recovery was 98% with a standard deviation of 2%.

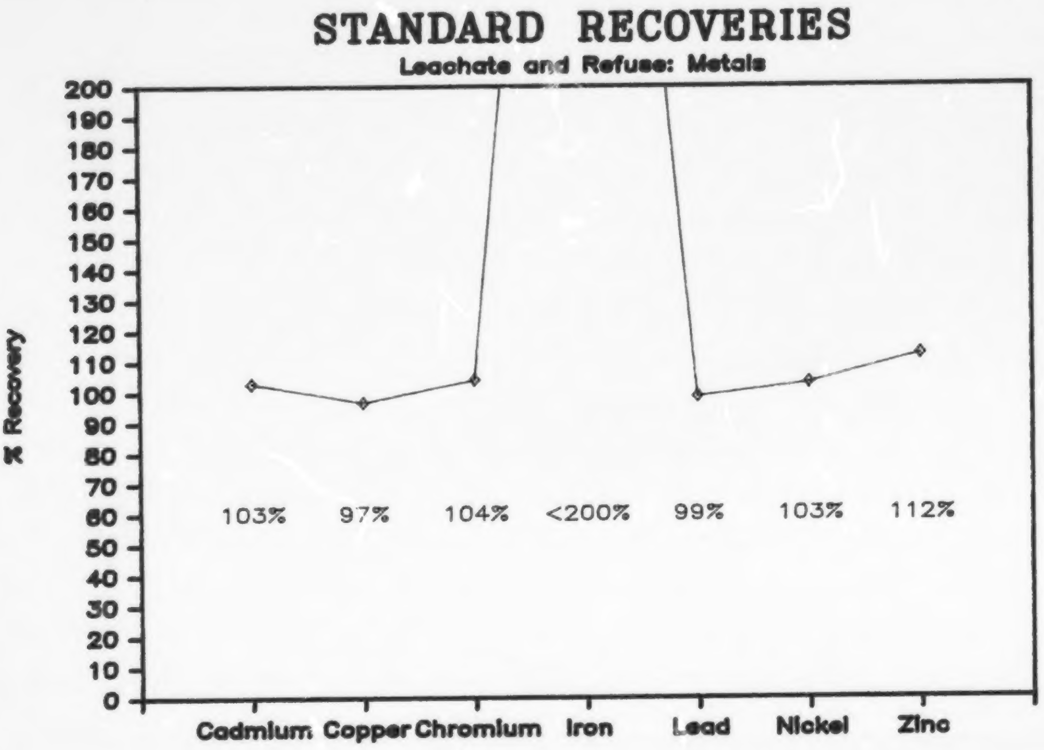

Figure 6.

Cadmium

The average standard recovery based on two standards is 103% with a standard deviation of 0.4% (Figure 6). This suggests that reported results essentially reflect no bias. Two samples, representing approximately 5% of the total samples analyzed, were spiked. The mean spike recovery was 92% with a standard deviation of 1% (Figure 7).

Copper

The average standard recovery based on two standards is 97% with a standard deviation of 0.007%. This suggests that reported results essentially reflect no bias. Two samples, representing approximately 5% of the total samples analyzed, were spiked. The mean spike recovery was 91% with a standard deviation of 5%.

Chromium

The average standard recovery based on two standards is 104% with a standard deviation of 2.3%. This suggests that reported results essentially reflect no bias. Two samples, representing approximately 5% of the total

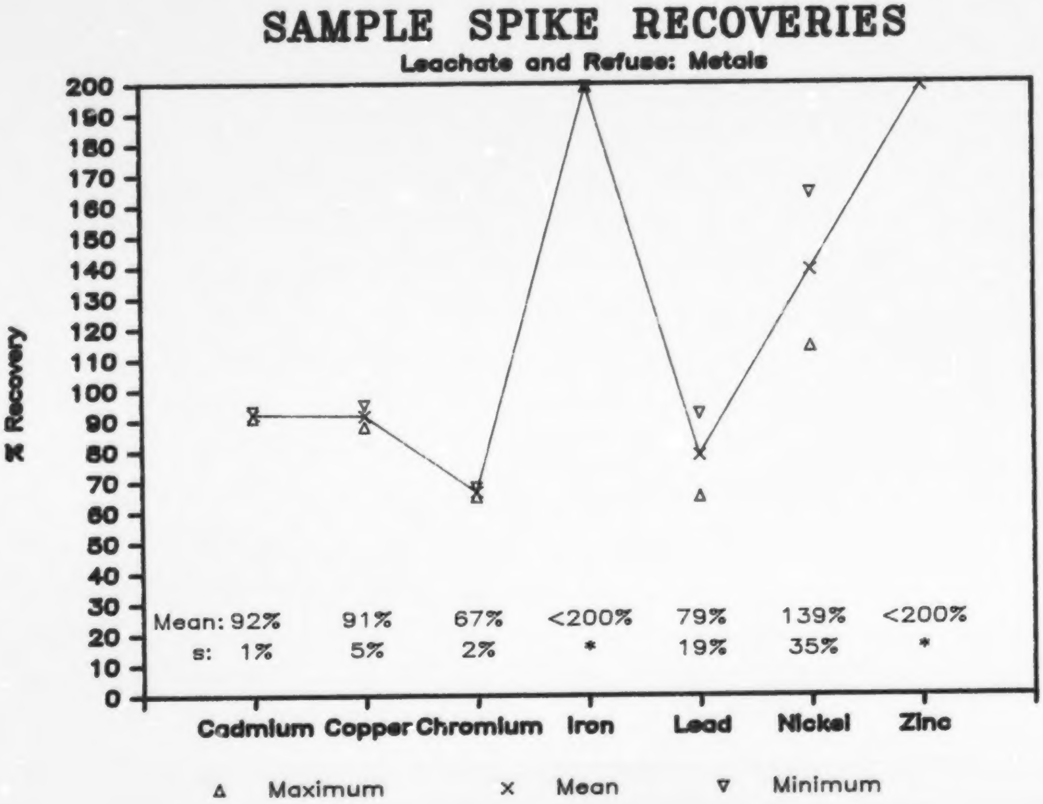

Figure 7.

samples analyzed, were spiked. The mean spike recovery was 67% with a standard deviation of 2%. This indicates the presence of an inhibiting interference in the matrix which may result in reported chromium values as much as 40% lower than the true value.

Iron

Both the standard recoveries and the spiked sample recoveries have results that are greater than 200% recovery. This suggests that there is an iron interference in the analytical process.

Lead

The average standard recovery based on two standards is 99% with a standard deviation of 27.1%. This suggests that reported results essentially reflect no constant bias. Two samples, representing approximately 5% of the total samples analyzed, were spiked. The mean spike recovery was 79% with a standard deviation of 14%. With the standard deviation as large as it is and only two samples spiked, it is difficult to say if this low mean spike recovery is truly representative of an inhibiting interference or not.

Nickel

The recovery of a single QA standard is 103%. This suggests that reported results essentially reflect no bias. Two samples, representing approximately 5% of the total samples analyzed, were spiked. The mean spike recovery was 139% with a standard deviation of 35%. Again, as with the lead results, since the standard deviation is large and since there are only two samples spiked, it is difficult to say if this high mean spike recovery is truly representative of an enhancing interference or not.

Zinc

The average standard recovery based on 2 standards is 112% with a standard deviation of 6.5%. This suggests that reported results reflect a small positive bias. Two samples, representing approximately 5% of the total samples analyzed, were spiked. The mean spike recovery was greater than 200% for these samples. This would tend to suggest a positive interference in the matrix.

COMPLETENESS

Completeness is defined as the number of usable results obtained in terms of the total number of results expected for each analysis. All analyses were 100% complete, except for the two gravel analyses and the Fe results. Due to contamination problems, the Fe results were not usable and, therefore, Fe was considered 0% complete. Gravel samples from cells 16 and 19 were not analyzed, making the sulfide and COD analyses on the gravel 90% complete. With the exception of iron, the analyses were sufficiently complete to provide adequate amounts of data for evaluation.

REPRESENTATIVENESS

Representativeness is defined as the degree to which data accurately and precisely represent a characteristic of a population. This is generally addressed through adherence to prescribed sampling procedures which ensure that samples taken for analysis truly represent the entire material being sampled. Although every reasonable attempt was made to ensure representativeness of the samples, given the nature of the refuse in the lysimeters and the volume sampled (50 lbs) relative to the total volume in the lysimeters, it would be reasonable to assume that obtaining samples representative of the entire lysimeter would be extremely difficult, if not impossible. The refuse was clearly heterogeneous throughout and even though samples were taken such as to minimize this problem, there is undoubtedly still some effect. Furthermore, microbiological samples were taken so that the non-biodegradable constituents (e.g. glass, plastic, etc.) were intentionally excluded. It would be reasonable to assume that the samples taken represent typical municipal landfill samples; however, they do not necessarily represent the entire contents of the lysimeter from which they were obtained.

COMPARABILITY

Comparability is defined as the confidence with which one data set can be compared to another. Data generated by this project are readily comparable to other similar data, since all methods (with the exception of the methane producer analysis) are standard procedures. Furthermore, all results have been reported in standard reporting units. All solid waste results have been reported in terms of both wet and dry weight in order to maximize comparability. When data are compared with other similar data, the problems encountered with sample representativeness should be kept in mind. The overall effect would tend to make data comparable in a broad, general sense only.

SUMMARY

Microbiological Analyses

MPN Tests: Total Coliforms, Fecal Coliforms, Fecal Streptococci, Stormy Fermentation

No additional QA/QC procedures were performed on the MPN tests beyond those built into a traditional MPN test. Each MPN analysis is designed such that several nested levels of isolation and identification ensure that a high percentage of the results will be accurate. Even though five fermentation tubes were used, precision of the results obtained is generally not considered to be of a high order. This can be seen in the tables of the MPN 95% confidence limits found in *Standard Methods for the Examination of Water and Wastewater*. Although the MPN index was used to estimate the true bacterial density in the samples, the 95% confidence limits have not been included herein. Caution must be exercised when interpreting the significance of the MPN results from this project. It should be stressed that the most significant information obtained from the MPN tests is the presence of the indicator organisms in relatively high numbers, not the actual numbers obtained.

Plate Counts: Standard Methods-Aerobic, Standard Methods Anaerobic, MacConkey, Rose Bengal

Precision for all plate counts is based on the actual number of colonies counted on duplicate plates. Considering the potential variability when dealing with microorganisms, the duplication seen on this data was quite acceptable. Based on the information presented earlier, duplicate plate counts would be ±10% to ± 20% of the mean reported value. Accuracy of these analysis relied heavily on analyst experience. It is difficult to eliminate this dependency; however, it is minimized through the use of Standard Reference Cultures which ensure that the desired organism(s) will, in fact, grow on the media prepared for that purpose.

Identification Tests

There were no QA/QC quantifications associated with the microbial identification tests. Nested levels of isolation ensured a high probability of accurate results. The identifications relied heavily on analyst experience and knowledge. Unfortunately, there is no way to quantify this into simple precision and accuracy statements.

Enrichment Tests: Methane Producers

The methane producer test was basically used as a qualitative test for the presence or absence of methane producing bacteria. This was accomplished by quantifying methane levels in the test vials. The data generated are clearly usable for this purpose.

Solid Waste, Gravel and Leachate

ORP, Conductivity, pH, Sulfide

No attempt was made to quantify the degree of precision or accuracy associated with these four analyses. The instruments for ORP, pH and conductivity were calibrated with appropriate standards. Past systems audits have indicated these instruments perform accurately when calibrated with such standards. The semi-quantitative sulfide analysis has a limited level of precision and accuracy, simply by the nature of the analysis. However, since the data was only used to indicate the presence or absence of sulfide in the gravel residue, the lack of QC information does not hinder the data usability for this project.

% Moisture, Alkalinity, Total Solids, Total Volatile Solids

Only precision was estimated for these analyses, since these procedures are not amenable to spiking, nor are routine QA standards easily prepared. All of these analyses showed good short term precision and can be considered valid for this project.

COD, TOC, TKN, Chloride, Total Phosphate

These analyses showed both acceptable precision and accuracy for all project data. All results from these analyses can be considered valid for this project.

Metals: Cd,Cr,Cu,Fe,Pb,Ni,Zn

The Cd, Cr, Cu and Ni analyses showed a great deal less reproducibility than the other metals analyses. This was largely due to the relatively low concentrations of these metals in the samples. Although this data is useable for this project, it should be kept in mind that this information does not maintain a very high degree of precision at these very low concentrations. Fe, Zn and Pb tended to have higher concentrations and these results were very reproducible.

Accuracy based on standards and spikes for Cd, Cu, Pb and Ni is very high with little to no apparent bias. The reported results for these analyses are certainly valid for this project. Reported Cr results are probably somewhat lower than the true values based on sample spike recoveries. Since Cr standards suggest no bias in the analysis, the inhibited spike recoveries are probably the result of a matrix interference. Both Fe and Zn showed extremely high spike recoveries. This is often indicative of sample contamination or matrix interferences. When contamination alone is the problem, results of QA standards and blanks behave similarly. Iron standards showed very high recoveries (>200%) and blanks showed concentrations of approximately 0.30 mg/l Fe. This information confirms the presence of an iron contamination. The cause of the contamination is under investigation. However, this problem renders the Fe data generated as highly suspect, and the data should not be used. The data generated has been included in spite of the problems, simply to indicate that iron was clearly present in the samples and that it was probably present in fairly high concentrations.

Zn standards suggest some positive bias, but certainly do not account for the high spike recoveries obtained. This would tend to suggest a sample matrix interference creating reported results that are high. Zinc results may be somewhat high and should interpreted with this in mind.

Permeability

Only precision of the permeability measurements could be estimated. Reproducibility was very high on these measurements, and this data is considered valid for this project.

Based on the assumption that the data generated on this project is intended to be used in a general, relative sense, all of the data except for the iron results can be considered acceptable for this purpose. Although QC data was not or could not be generated for all analyses, this does not seriously effect the useability of this information. Caution should be exercised when interpreting the microbiological MPN results, the zinc data, and the chromium data.